

# COVID-19 Confirmed Cases Prediction as of March 31, 2020

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This report updates predictions for the number of COVID-19 confirmed cases 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 3 versions of the generalized logistic growth equation to model the total number of confirmed cases, resulting in a positive, medium and negative scenario for the final expected number of cases. 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.

**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, we report the prediction results 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 numbers per million population based on the positive and medium scenario.
- In Figure 2, we show the 1-day prediction error of yesterday's report.

### A summary of the situation:

- We can see a positive signal in Europe that seems to have reached the peak of the daily confirmed cases, with decreasing growth rate from 14.4% five days ago to 8% today. If this trend continues, we expect Europe to reach 750 thousand total confirmed cases in three weeks when it is then possible that the outbreak is under control.
- Numbers in Spain, Switzerland, Italy, Austria, and maybe Germany today continue to support the emerging signs of approaching the inflection point<sup>1</sup>, and all of them except Switzerland have converged ensemble distribution of the estimated final total confirmed numbers per million people. The situation in the US is still highly uncertain given that their testing rate has been increasing rapidly recently. 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 epidemics<sup>2</sup>.
- The remaining countries have distributions that have not converged, exhibiting exceedingly broad dispersion. Among them, France, Netherlands, UK and Belgium seem to develop signs of approaching the inflection point, while Turkey is still at an early stage, so its signal of approaching the inflection point may not be reliable. Confirmed infections in Japan continue to follow an exponential growth with a relatively low daily growth rate at 5-10%, while deaths are following a linear trend, indicating that there is not yet a large epidemic in Japan.

**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 rate, 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.**

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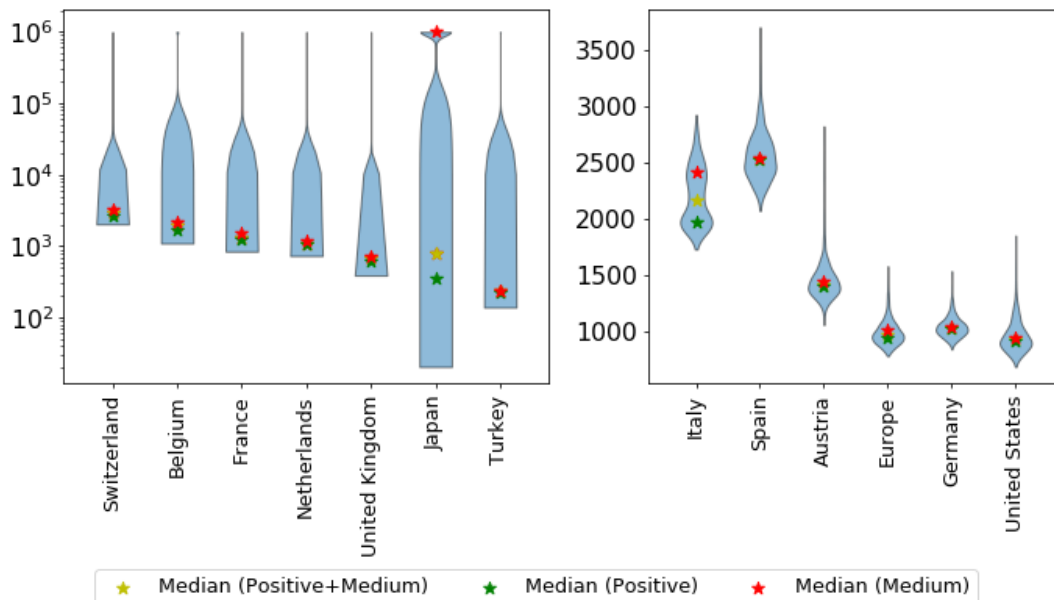
<sup>1</sup> On a logistic curve, the inflection point indicates where the curvature changes its sign. As we model the total number of confirmed cases, it is equal to the peak of the daily increase curve, after which the daily number of cases is decreasing. If the inflection point has been passed, the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

<sup>2</sup> One 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?

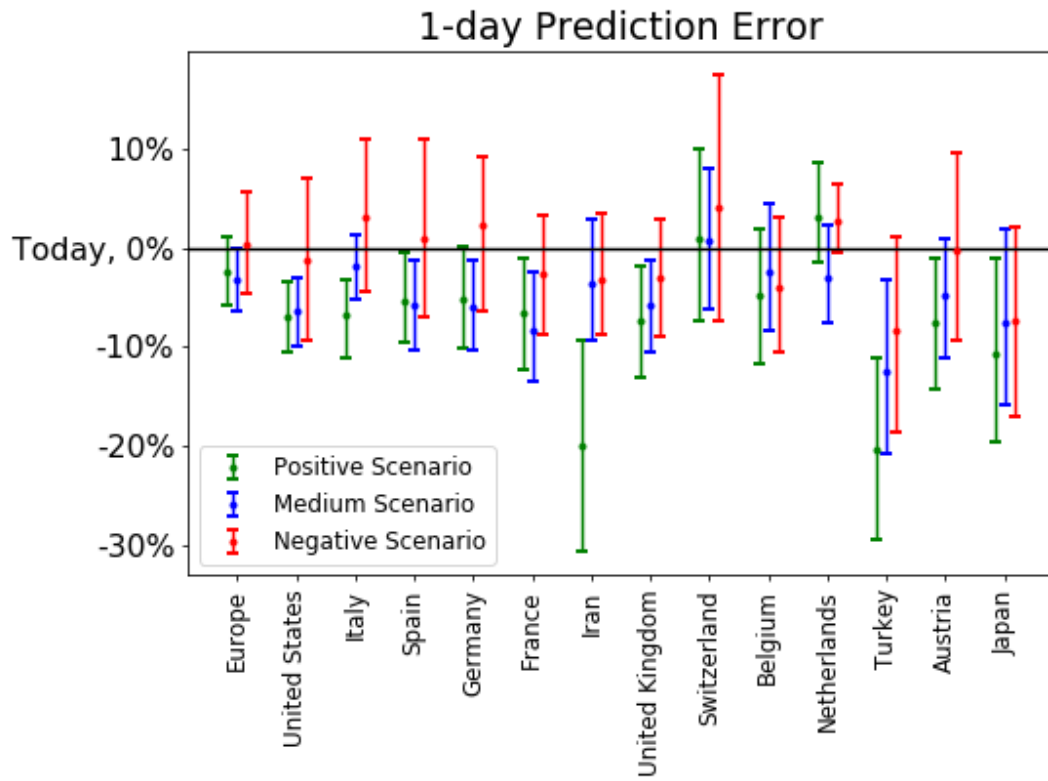
**Table 1.** Current confirmed cases per million population and estimated outbreak progress in positive and medium scenarios (today's confirmed cases divided by the estimated total final confirmed cases in positive and medium scenario). Numbers in brackets are 80% confidence intervals. As positive scenarios predict a smaller final number of total infected cases, the outbreak progress is thus larger in the positive scenario.

	Confirmed per Million Population (Mar-31)	Outbreak Progress in Positive Scenario	Outbreak Progress in Medium Scenario
Spain	1823	72.0% (65.4%, 78.4%)	71.6% (63.1%, 79.6%)
Switzerland	1810	67.9% (53.6%, 77.8%)	56.8% (37.8%, 70.5%)
Italy	1684	85.3% (80.0%, 90.0%)	69.7% (63.5%, 75.9%)
Austria	1087	77.2% (67.6%, 84.3%)	75.5% (64.9%, 83.2%)
Belgium	1042	62.3% (36.6%, 78.8%)	47.6% (5.3%, 60.6%)
Germany	747	72.9% (64.9%, 80.2%)	72.1% (63.7%, 78.6%)
Netherlands	682	63.9% (56.2%, 71.4%)	57.8% (35.2%, 76.1%)
France	665	53.6% (39.8%, 65.5%)	44.2% (21.0%, 60.4%)
Europe	562	59.8% (52.8%, 65.7%)	55.7% (47.6%, 62.6%)
United States	503	54.7% (44.4%, 63.0%)	53.3% (41.7%, 61.3%)
United Kingdom	333	54.3% (42.1%, 65.3%)	46.4% (30.3%, 53.9%)
Turkey	140	61.7% (38.0%, 78.1%)	59.2% (25.9%, 70.7%)
Japan	15	Not Reliable	Not Reliable

**Ensemble Distribution of Final Confirmed Cases per Million Population**



**Figure 1.** Violin plot of the distributions of the final total number of confirmed cases per million derived by combining the distributions of the positive and medium scenarios. 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 per 1 million of population, the results are deemed to be unreliable (Table 2).



**Figure 2.** One-day prediction error of the 14 countries/regions. The horizontal line corresponds to today's empirical data. For most countries except Switzerland, Belgium, The Netherlands and Europe taken as a whole, the positive scenario forecasts (and most of the medium scenario forecasts) have undershot the realized value, indicating a lack of stabilization of the dynamics of the epidemics.

**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	1-Apr	5-Apr	10-Apr	Final Total Confirmed
Europe	Positive	(396, 425) 420	437 (423, 453)	549 (525, 578)	636 (594, 690)	702 (639, 795)
	Medium	(393, 419) 420	432 (419, 447)	550 (529, 577)	652 (611, 710)	754 (670, 882)
	Negative	(401, 444) 420	455 (430, 484)	649 (611, 694)	969 (893, 1060)	Not Reliable
United States	Positive	(147, 159) 165	177 (170, 185)	244 (226, 266)	285 (253, 332)	301 (261, 371)
	Medium	(148, 160) 165	177 (169, 184)	245 (228, 267)	289 (258, 339)	309 (268, 395)
	Negative	(149, 176) 165	186 (171, 203)	323 (291, 363)	599 (494, 734)	Not Reliable
Italy	Positive	(90.5, 98.5) 102	98.5 (94.2, 103)	109 (105, 115)	116 (110, 122)	119 (113, 127)
	Medium	(96.4, 103) 102	103 (99.4, 106)	119 (113, 123)	131 (124, 138)	146 (134, 160)
	Negative	(97.3, 113) 102	109 (101, 118)	139 (128, 150)	183 (166, 199)	Not Reliable
Spain	Positive	(77.2, 84.8) 85.2	86.6 (82.8, 90.6)	105 (98.8, 111)	114 (106, 124)	118 (109, 130)
	Medium	(76.4, 84.1) 85.2	85.8 (81.6, 89.7)	104 (97.5, 111)	115 (105, 126)	119 (107, 135)
	Negative	(79.3, 94.4) 85.2	93.7 (83.8, 104)	139 (123, 154)	215 (183, 250)	Not Reliable
Germany	Positive	(55.7, 61.9) 61.9	63.3 (60.2, 66.3)	75.4 (70.8, 80.7)	82.1 (75.3, 89.9)	84.9 (77.2, 95.4)
	Medium	(55.5, 61.2) 61.9	63 (60, 65.6)	75.4 (71.1, 80.1)	82.5 (76.6, 90.4)	85.9 (78.7, 97.1)
	Negative	(58, 67.6) 61.9	68.1 (62.4, 74.1)	97.2 (88.7, 106)	145 (130, 164)	Not Reliable
France	Positive	(39.1, 44.1) 44.6	46.4 (43.8, 49.3)	60.6 (55.4, 66.5)	72.7 (63.4, 85.5)	83.2 (68, 112)
	Medium	(38.6, 43.5) 44.6	45.9 (43.3, 48.5)	61.5 (56.4, 68.4)	77.7 (65.9, 97)	101 (73.8, 212)
	Negative	(40.7, 46) 44.6	47.7 (45, 50.9)	69.6 (65.5, 74.9)	107 (98.9, 118)	Not Reliable
United Kingdom	Positive	(19.2, 21.7) 22.1	22.9 (21.7, 24.2)	32 (28.9, 35.7)	38 (32.7, 45.9)	40.8 (33.9, 52.6)
	Medium	(19.8, 21.9) 22.1	23.6 (22.5, 24.7)	34.2 (31.7, 37.8)	42.6 (37.9, 53.4)	47.7 (41.1, 73.2)
	Negative	(20.2, 22.8) 22.1	24.3 (22.7, 26.1)	41.8 (38, 45.1)	77.2 (66.9, 89.7)	Not Reliable
Switzerland	Positive	(14.3, 17) 15.4	16.5 (15.3, 18)	19.5 (17.7, 21.8)	21.4 (19.1, 25.3)	22.7 (19.8, 28.7)
	Medium	(14.5, 16.6) 15.4	16.7 (15.5, 17.9)	20.3 (18.5, 22.5)	23.4 (20.4, 28.1)	27.1 (21.9, 40.8)

	Negative	(14.3, 18.1) 15.4	17.3 (15.2, 19.5)	23.7 (20.8, 27)	33.4 (28.6, 39.8)	Not Reliable
Belgium	Positive	(10.5, 12.1) 11.9	11.8 (10.7, 12.9)	16.1 (13.8, 20.1)	18.3 (14.9, 27.3)	19.1 (15.1, 32.5)
	Medium	(10.9, 12.4) 11.9	12.4 (11.4, 13.4)	18.1 (15.9, 22.2)	22.5 (18.4, 39.3)	Not Reliable
	Negative	(10.7, 12.3) 11.9	12.9 (11.8, 13.9)	21.9 (19.8, 24.5)	39.8 (33.7, 49)	Not Reliable
Netherlands	Positive	(11.6, 12.8) 11.8	12.9 (12.3, 13.4)	15.8 (14.7, 16.8)	17.5 (15.9, 19.3)	18.4 (16.5, 20.9)
	Medium	(10.9, 12) 11.8	11.6 (10.9, 12.4)	15.2 (13.4, 17.6)	18 (14.8, 23.6)	20.3 (15.4, 33.4)
	Negative	(11.7, 12.5) 11.8	13.2 (12.6, 13.8)	19.5 (18.5, 20.5)	30.1 (28.2, 32.5)	Not Reliable
Turkey	Positive	(8.14, 10.3) 11.5	12.2 (11.1, 13.6)	17.3 (14.3, 22.7)	18.6 (14.7, 28.6)	18.7 (14.8, 30.4)
	Medium	(9.14, 11.2) 11.5	12.4 (11.3, 13.5)	17.8 (15.3, 25.3)	19.3 (16.2, 37.4)	19.5 (16.3, 44.5)
	Negative	(9.4, 11.7) 11.5	13 (11.9, 14.2)	29.1 (25.2, 34.8)	67.3 (51.8, 94.8)	Not Reliable
Austria	Positive	(8.25, 9.51) 9.62	9.88 (9.27, 10.6)	11.4 (10.6, 12.3)	12.1 (11.2, 13.5)	12.5 (11.4, 14.2)
	Medium	(8.56, 9.71) 9.62	9.92 (9.24, 10.5)	11.5 (10.7, 12.5)	12.4 (11.3, 13.8)	12.7 (11.6, 14.8)
	Negative	(8.72, 10.5) 9.62	10.4 (9.44, 11.5)	14.4 (12.9, 16.1)	20.4 (17.8, 23.5)	Not Reliable
Japan	Positive	(1.57, 1.93) 1.95	1.94 (1.76, 2.13)	2.56 (2.27, 2.85)	3.59 (2.86, 4.23)	Not Reliable
	Medium	(1.65, 1.99) 1.95	1.87 (1.71, 2.05)	2.52 (2.27, 2.81)	3.63 (3.03, 4.24)	Not Reliable
	Negative	(1.62, 1.99) 1.95	1.87 (1.72, 2.05)	2.54 (2.31, 2.79)	3.71 (3.21, 4.26)	Not Reliable
Iran	Positive	(28.8, 37.6) 41.5	36.6 (32.2, 41)	47.7 (38.9, 61.3)	57.5 (42, 98.2)	Not Reliable
	Medium	(37.6, 42.7) 41.5	42.8 (40, 46)	55.5 (50.8, 60.4)	74 (63.6, 82.6)	Not Reliable
	Negative	(37.9, 42.9) 41.5	43.1 (40.2, 46)	56.4 (52.3, 60.6)	76.1 (69.8, 83.1)	Not Reliable

\* Note:

- The scenarios are based on the final total confirmed numbers. The positive and medium scenarios are derived from the Generalized Logistic Model and the Logistic Model. The model with the lower mean predicted final total confirmed number  $K$ , is classified as the positive scenario, and the other 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.

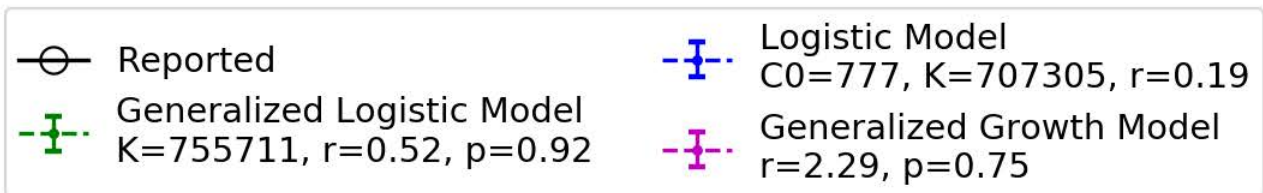
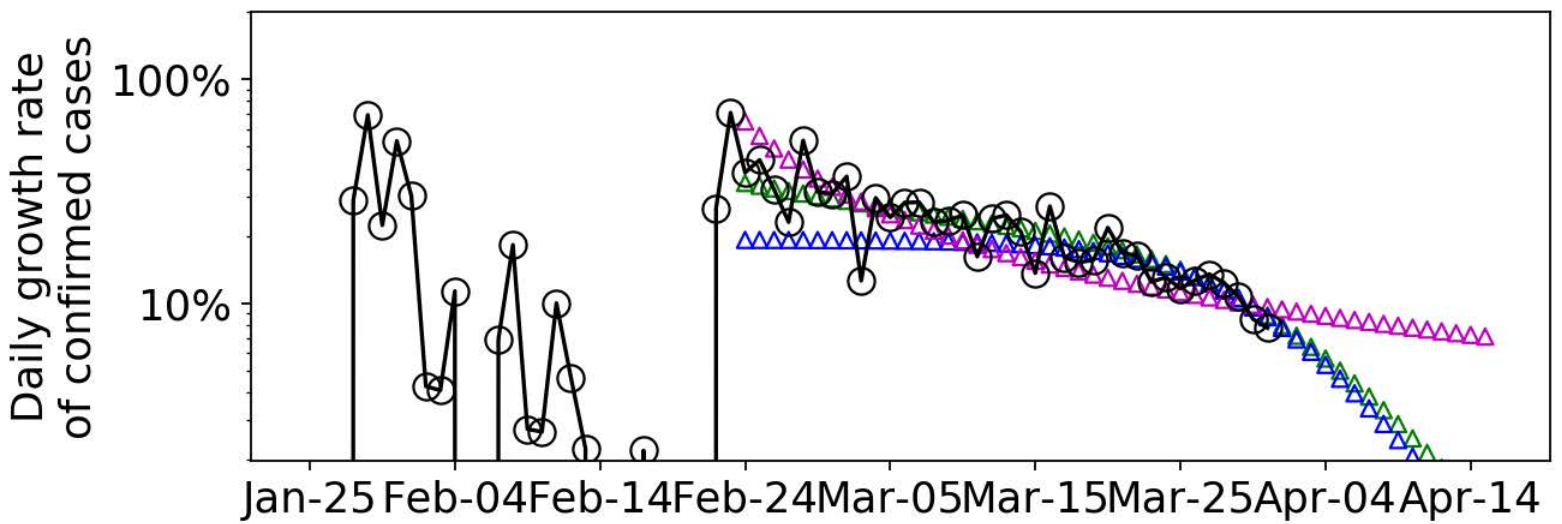
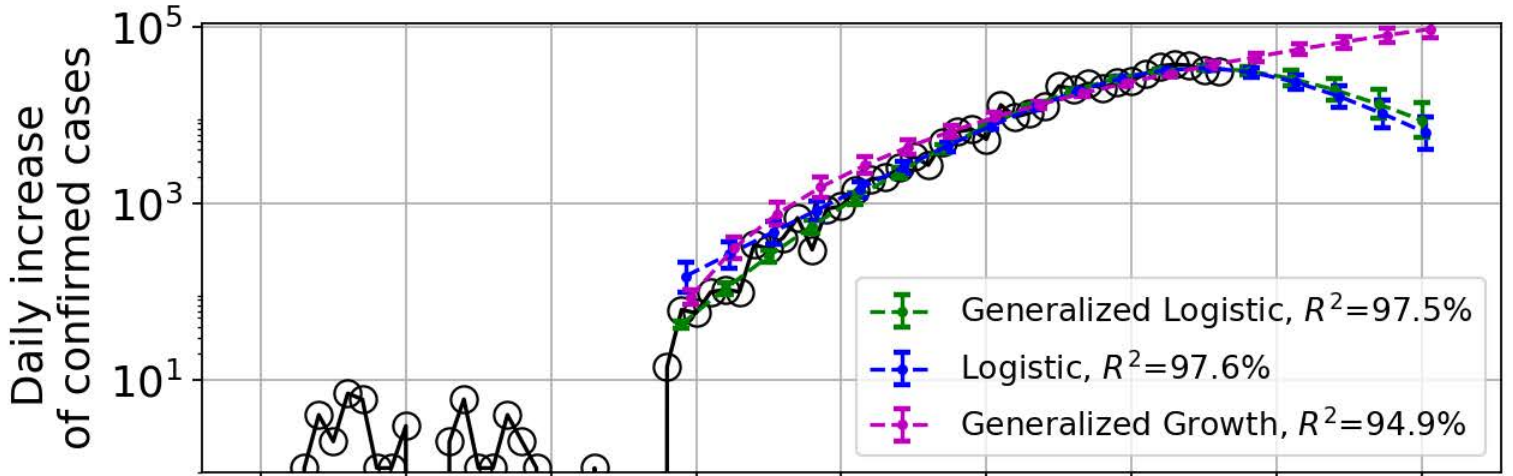
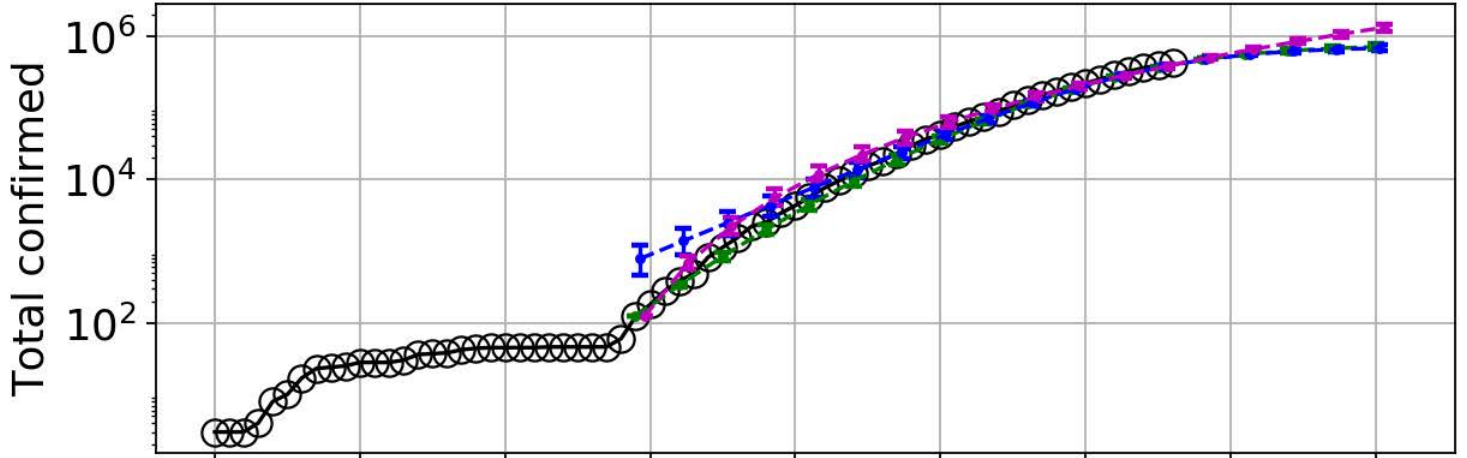
One final complication is the fact that tests are conducted sequentially over time. They do not represent a snapshot of a day in time. Many of those tested early, giving a negative result, may today get a positive result. And many, who tested positive early on, may today be cured.

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>

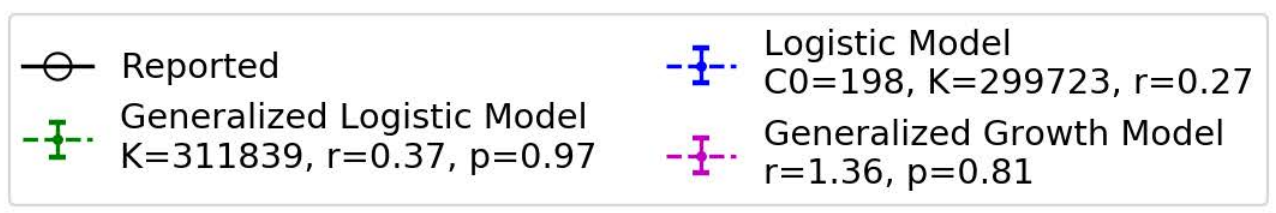
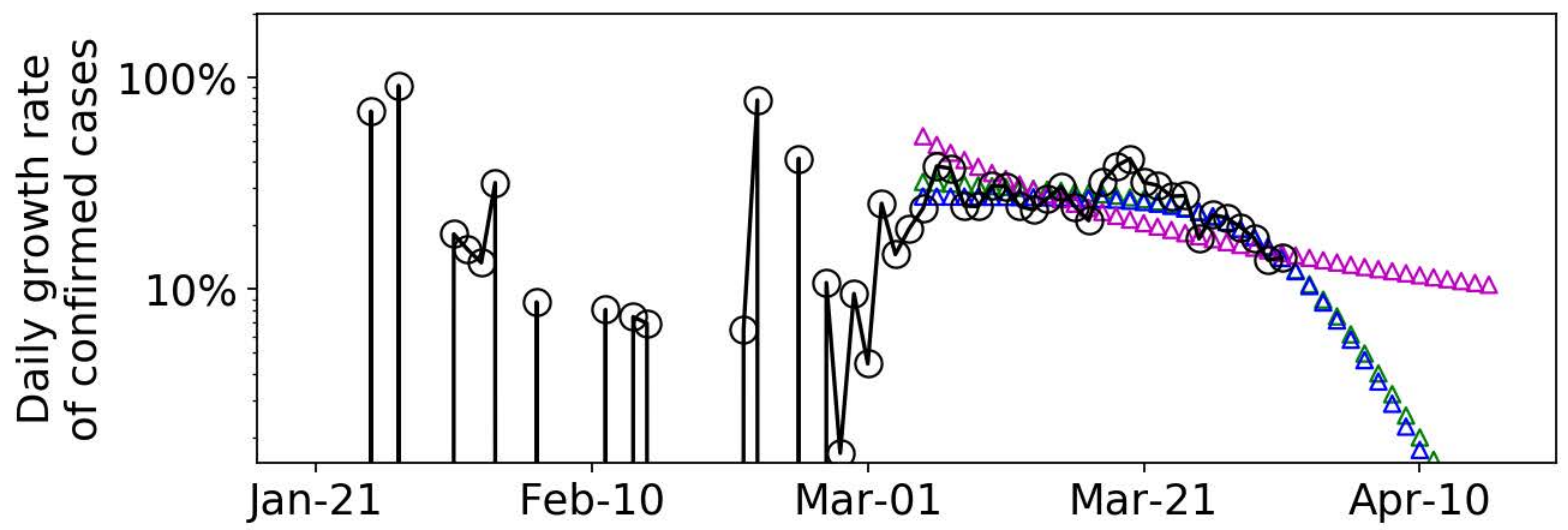
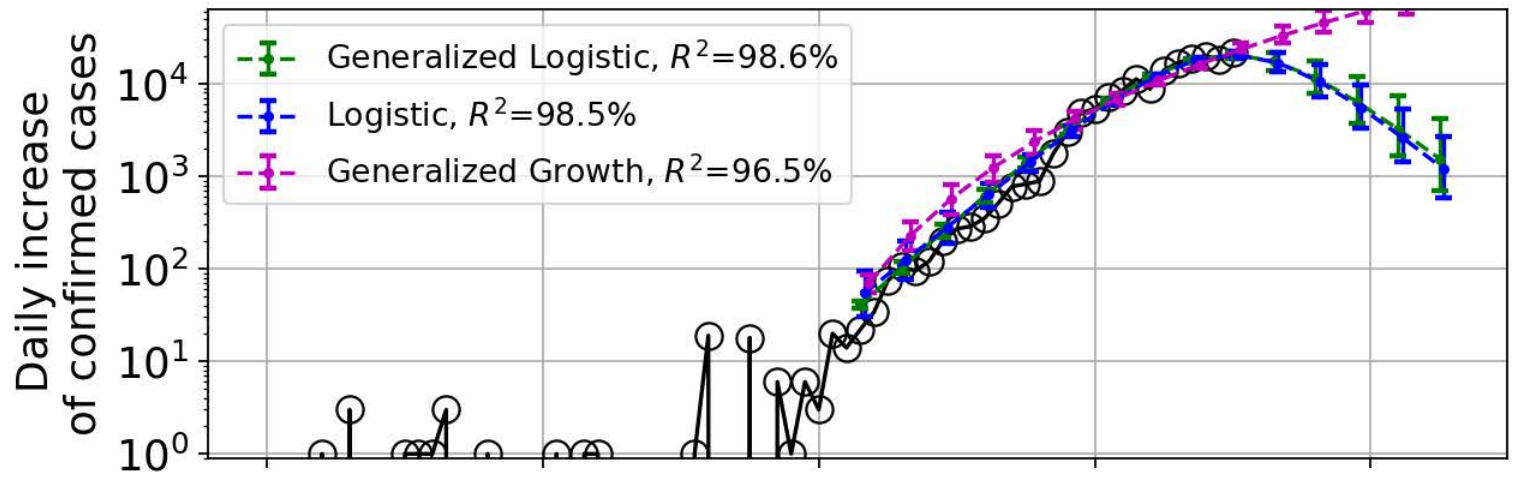
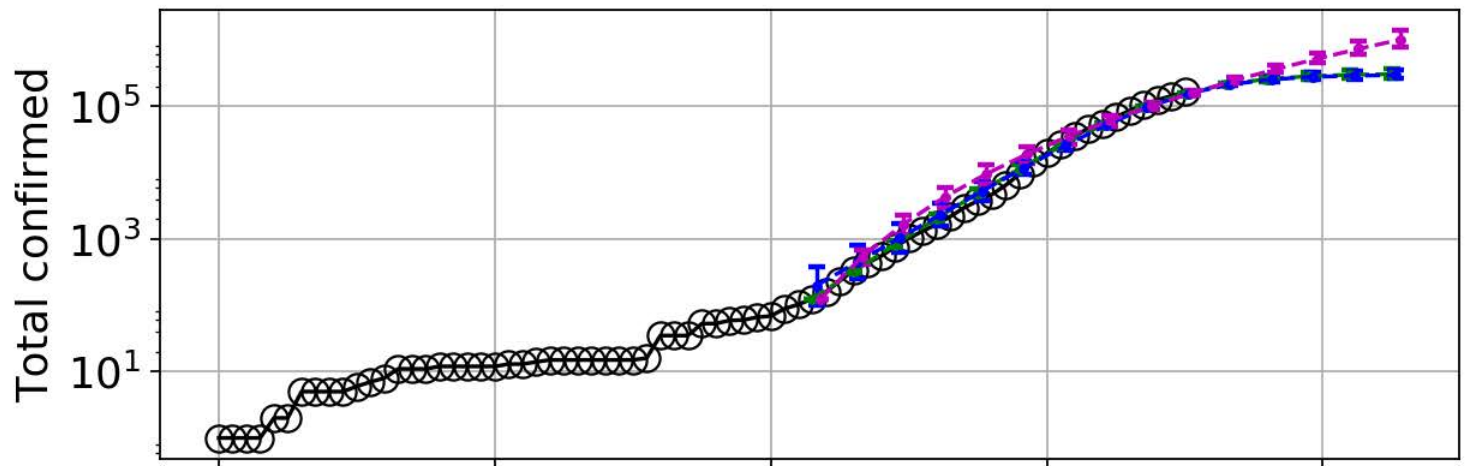
[2] <https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases>

# Europe

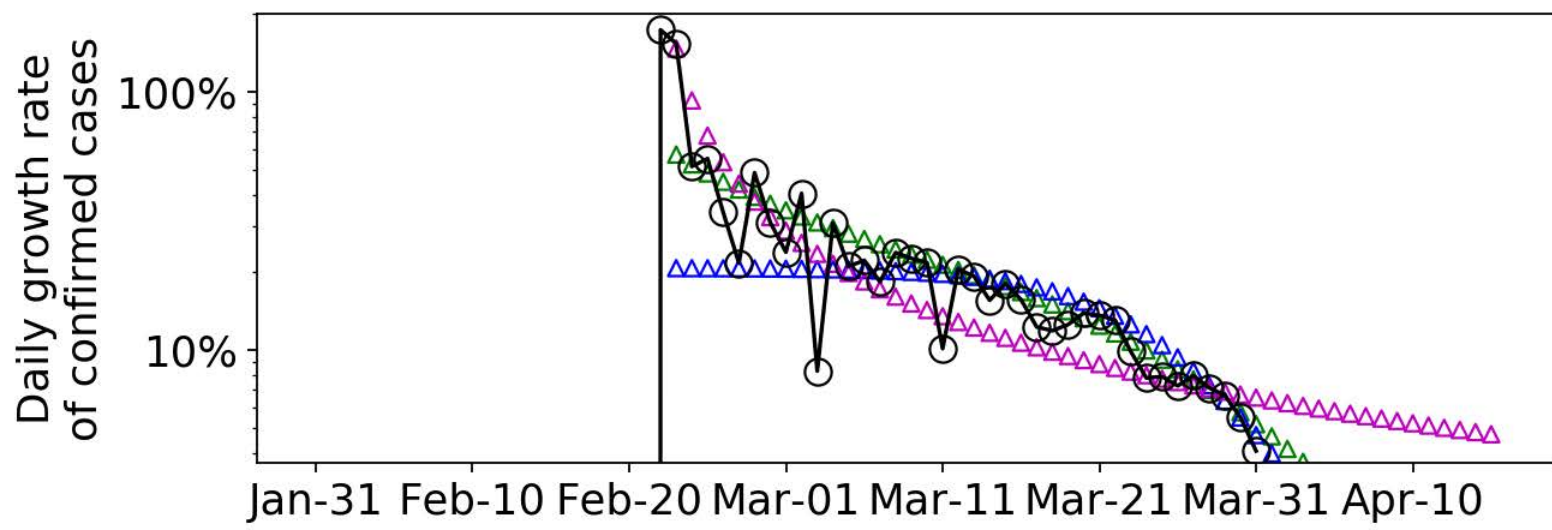
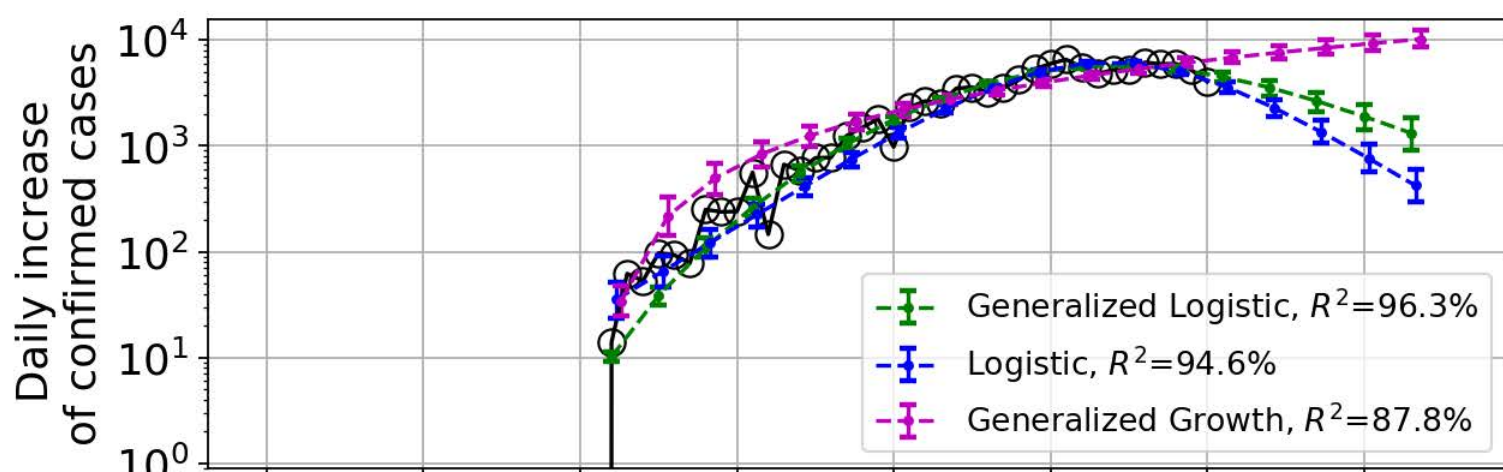
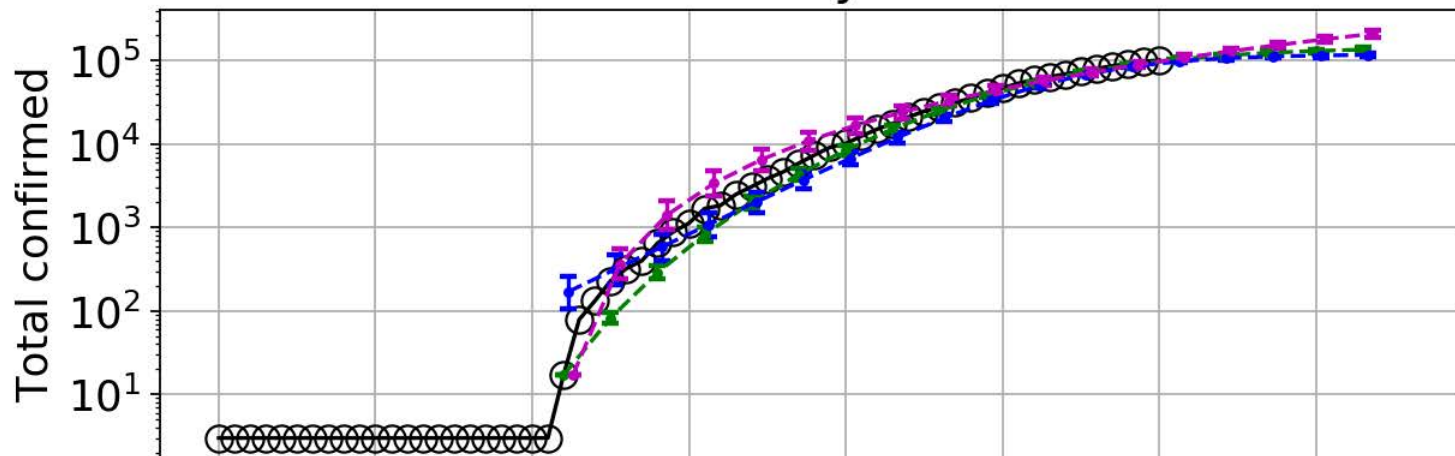




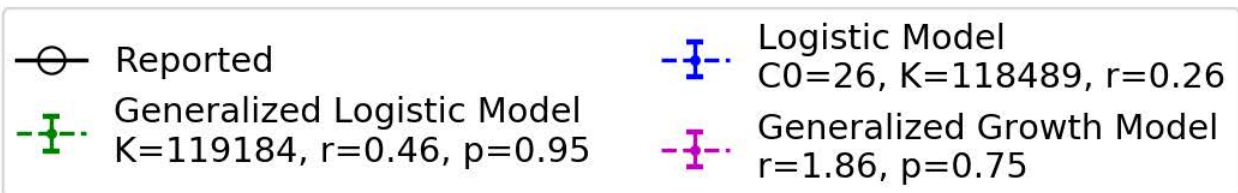
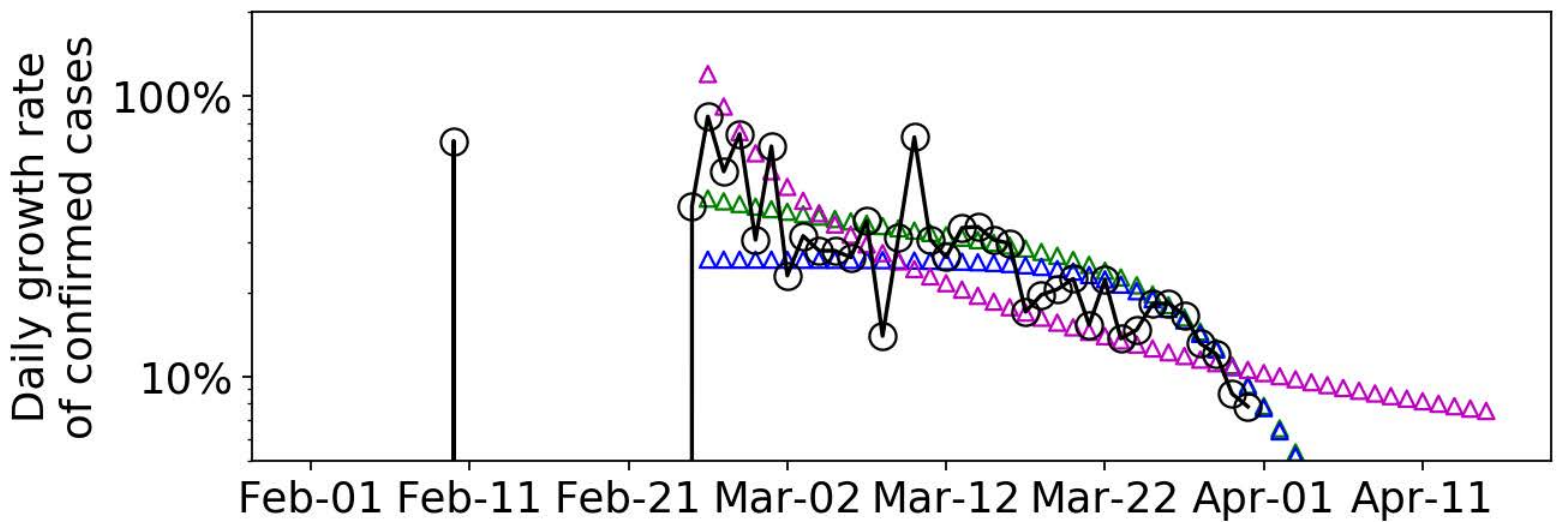
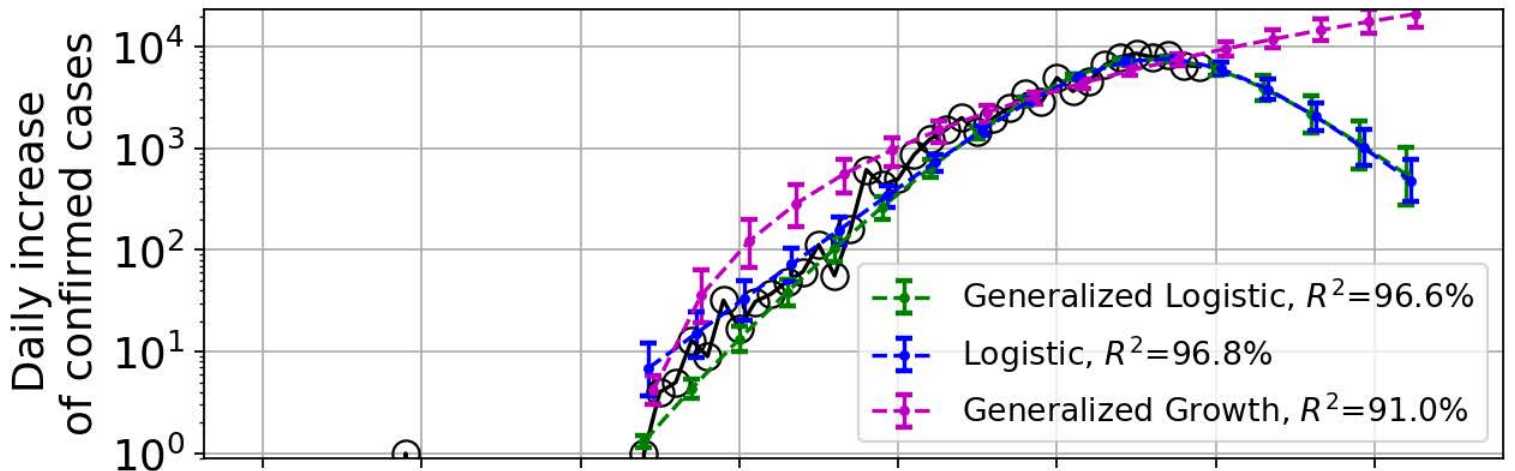
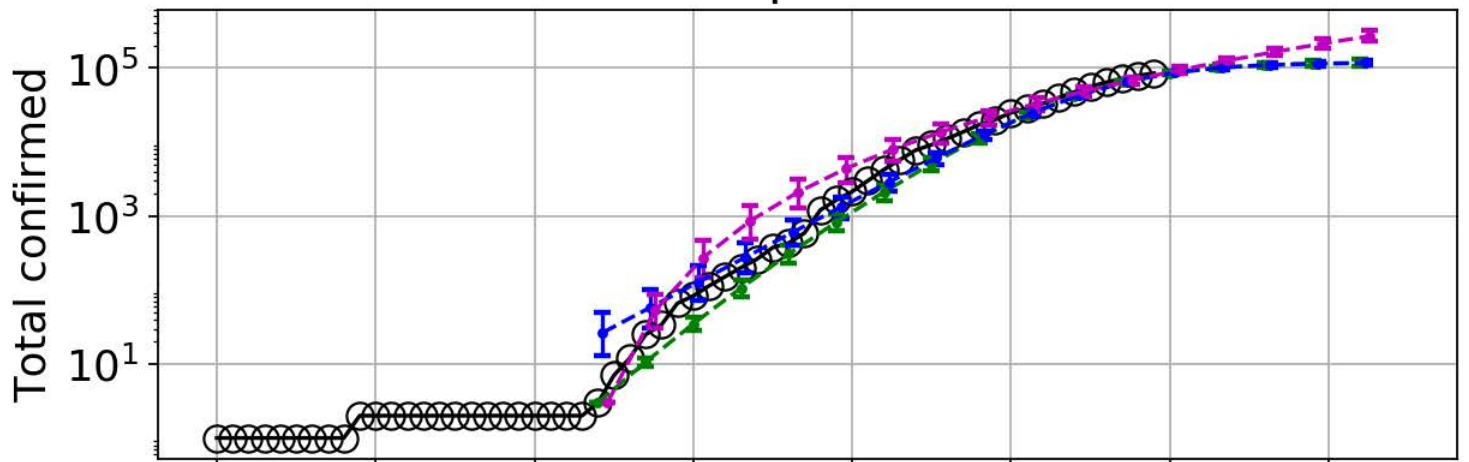
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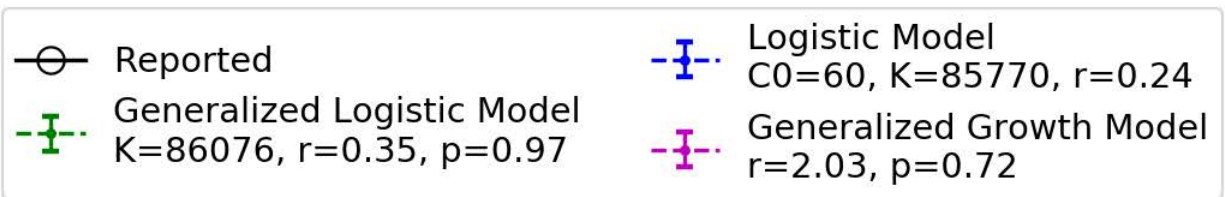
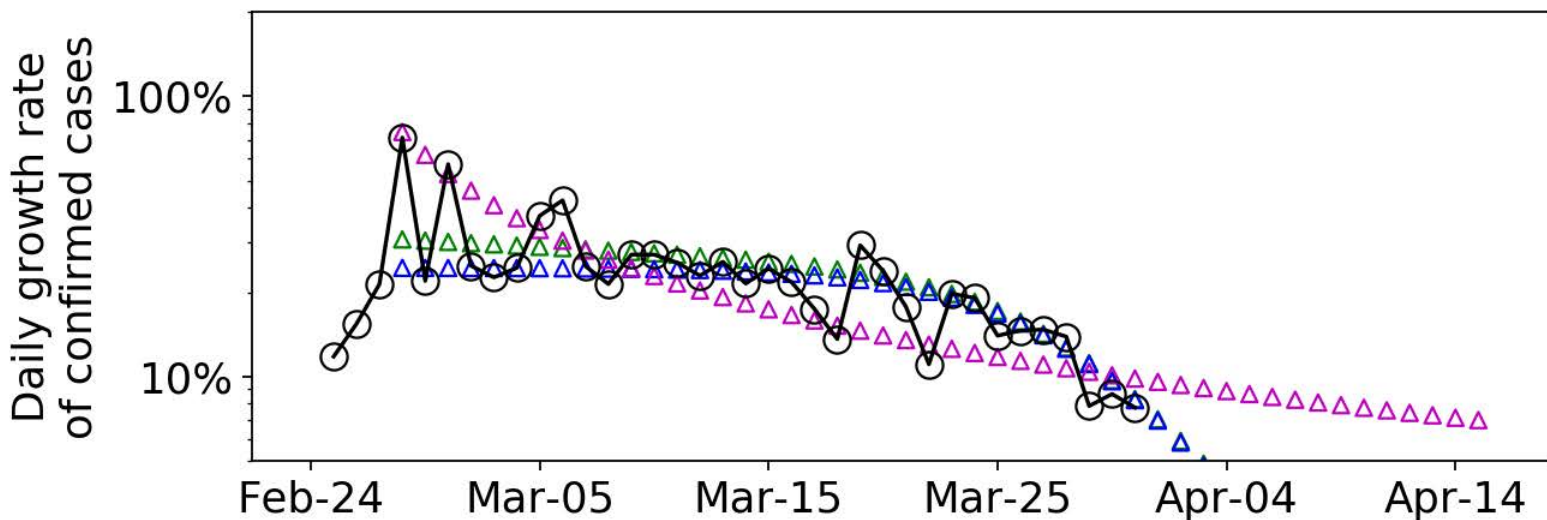
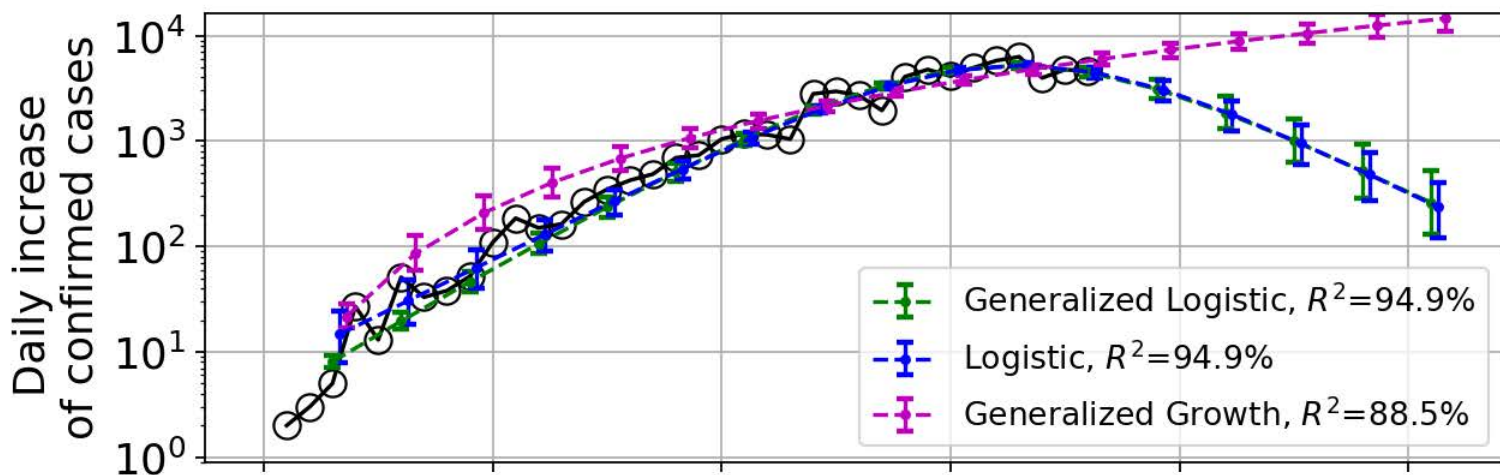
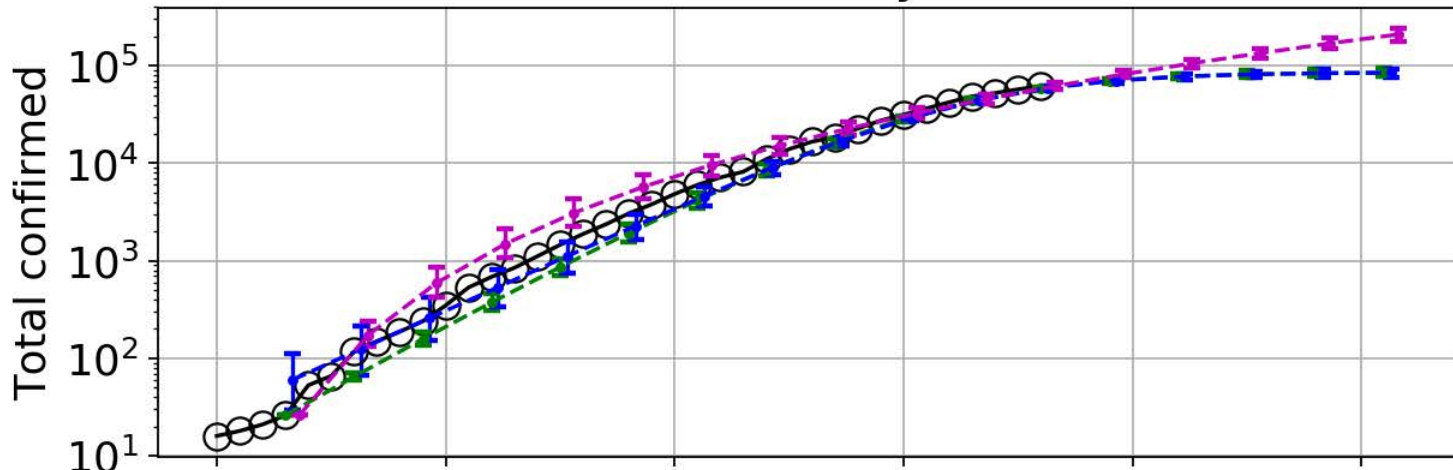
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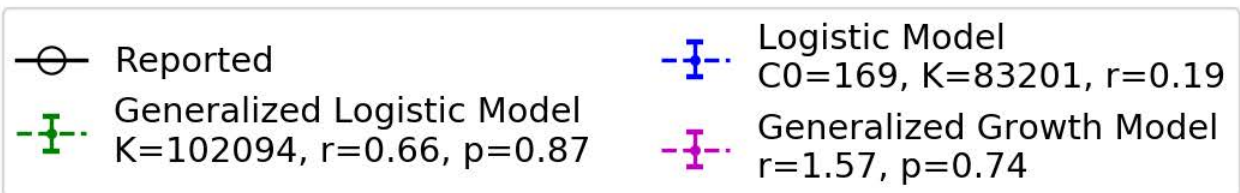
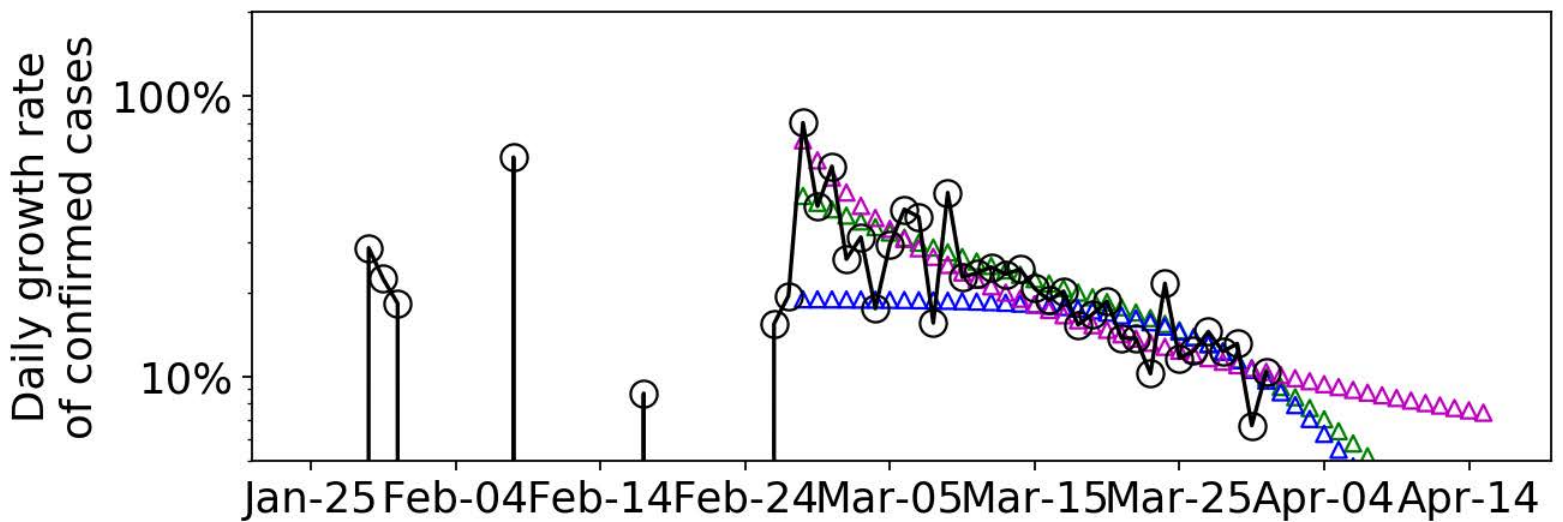
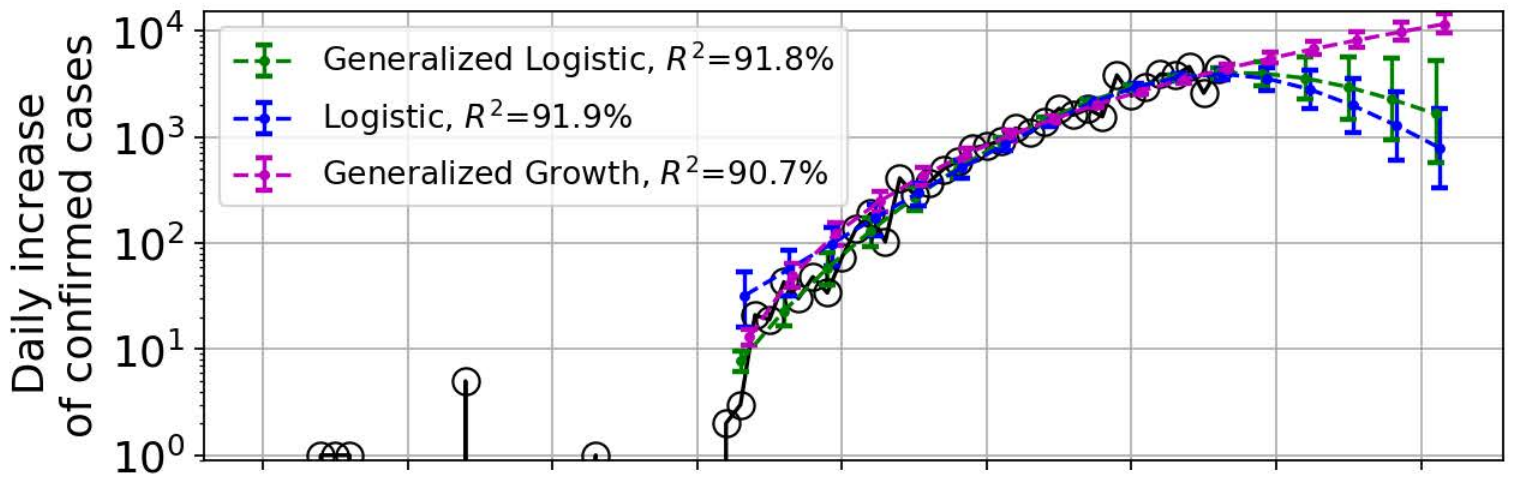
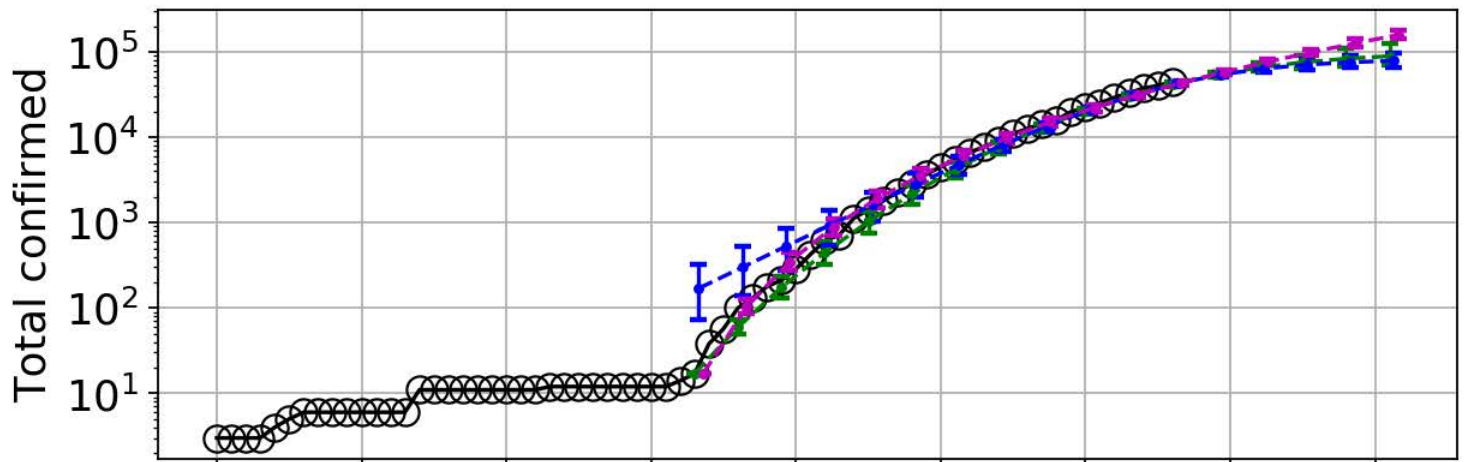
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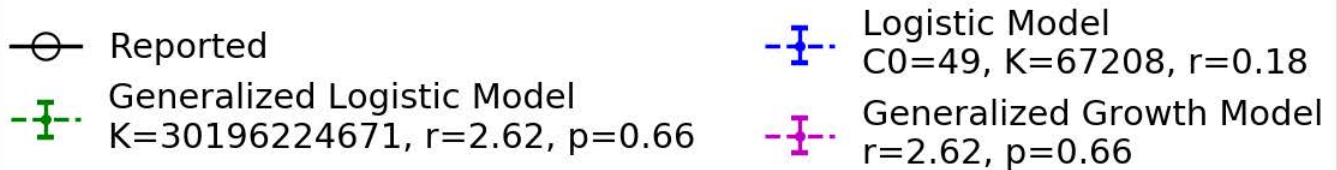
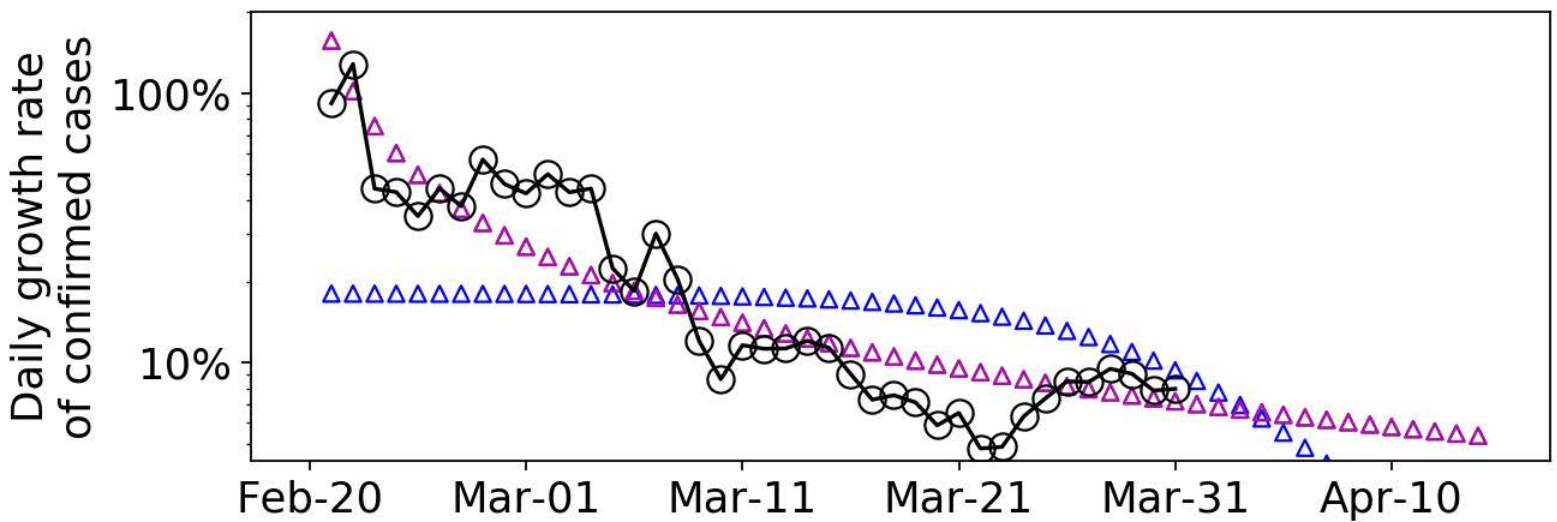
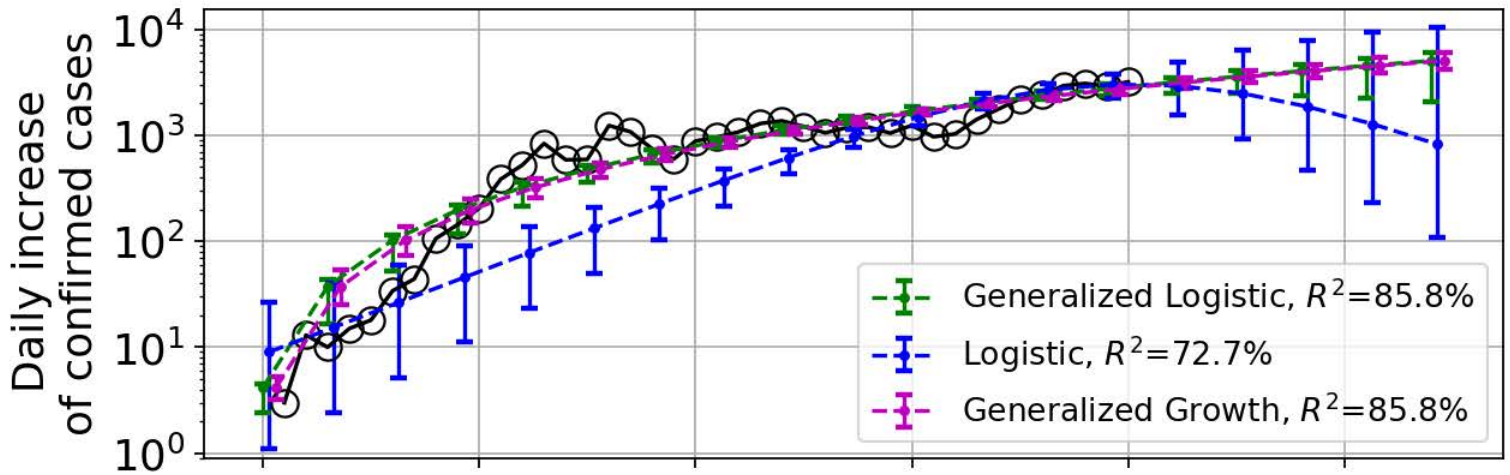
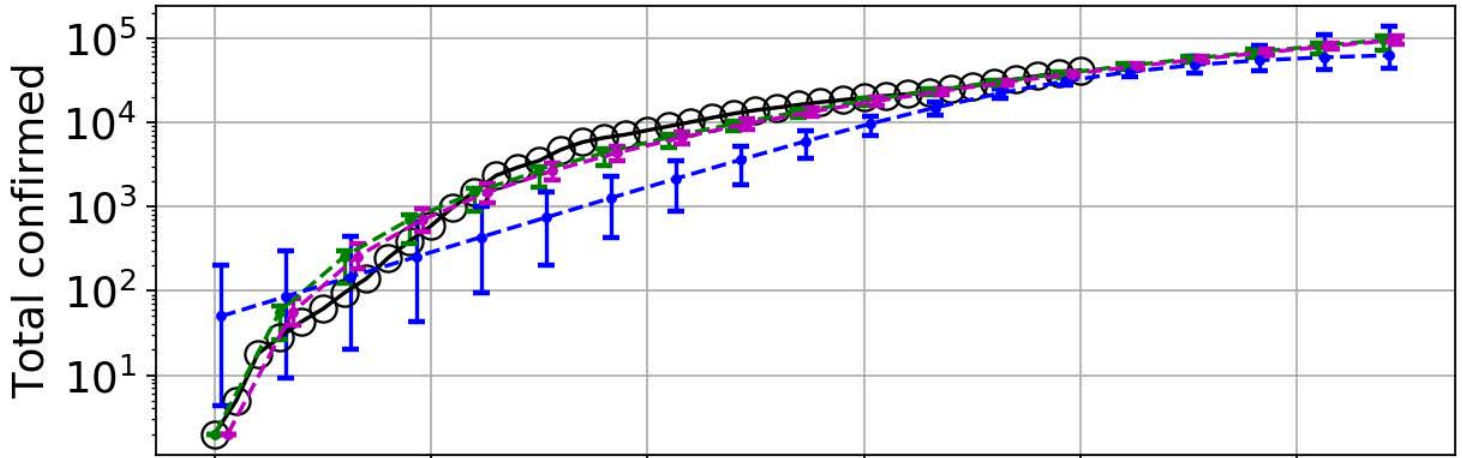
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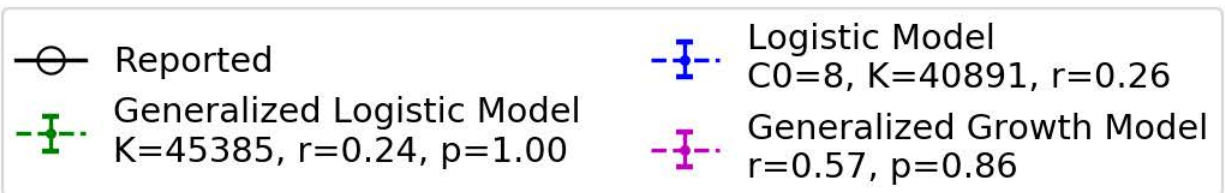
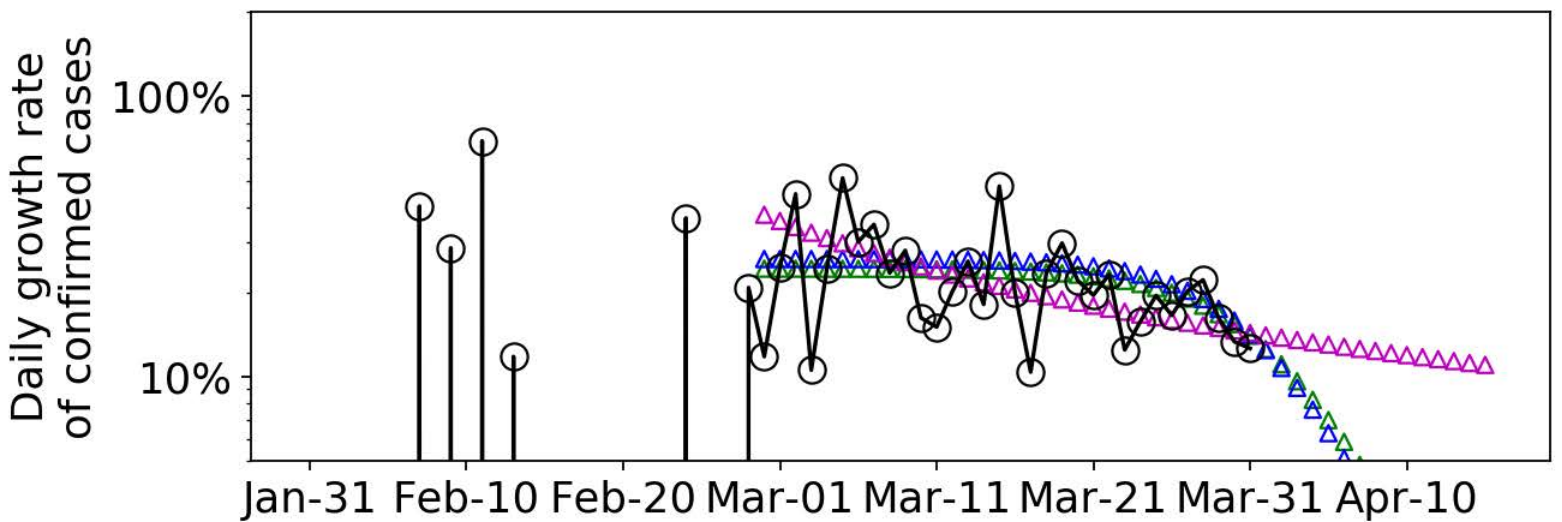
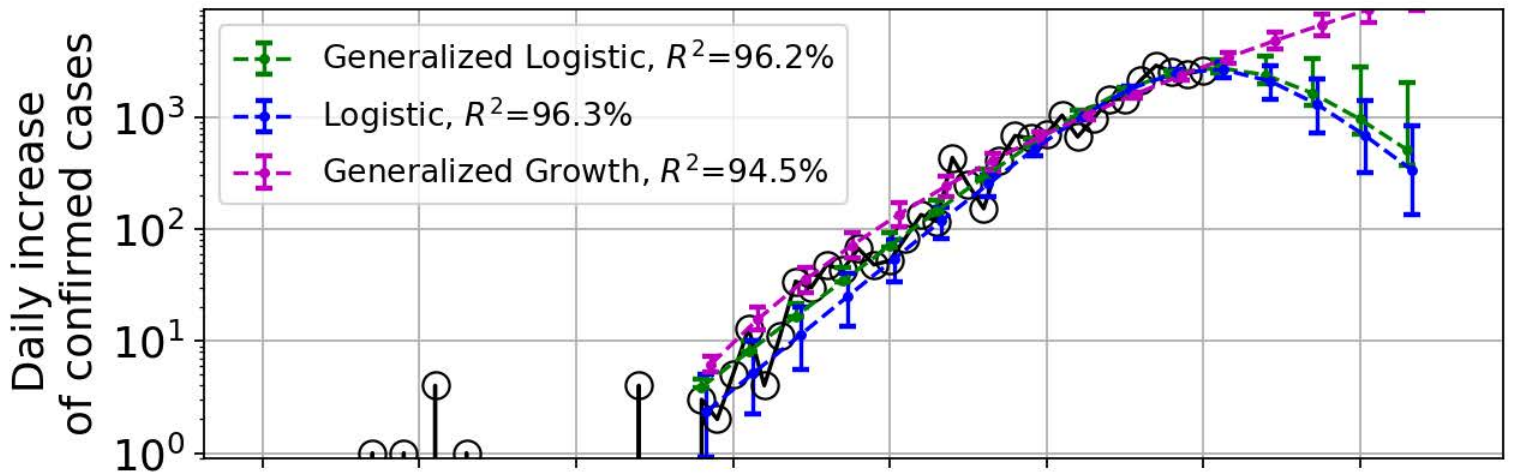
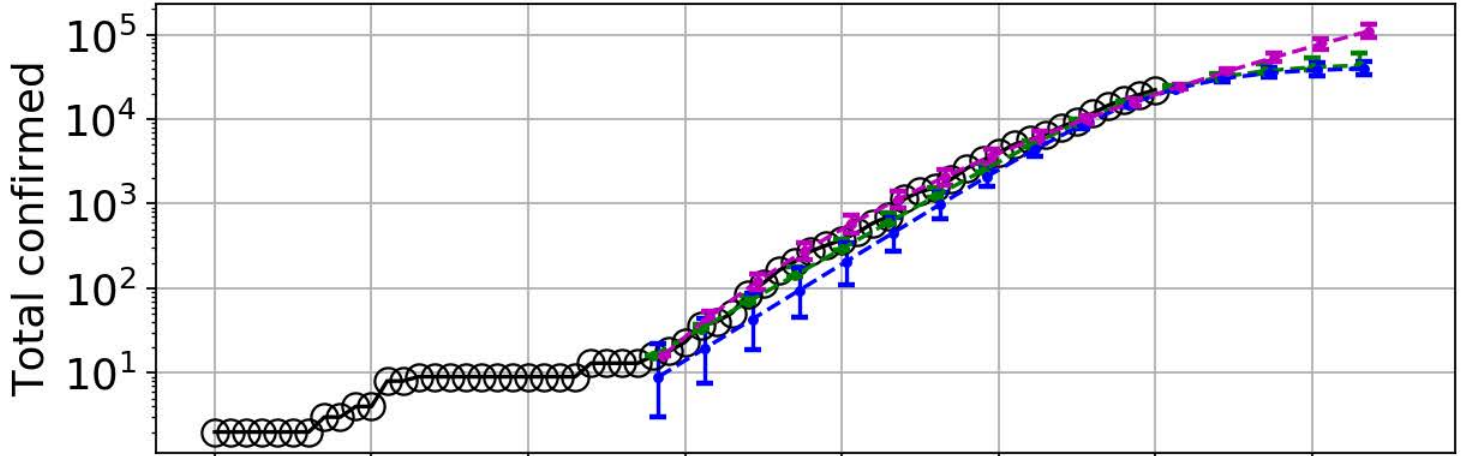
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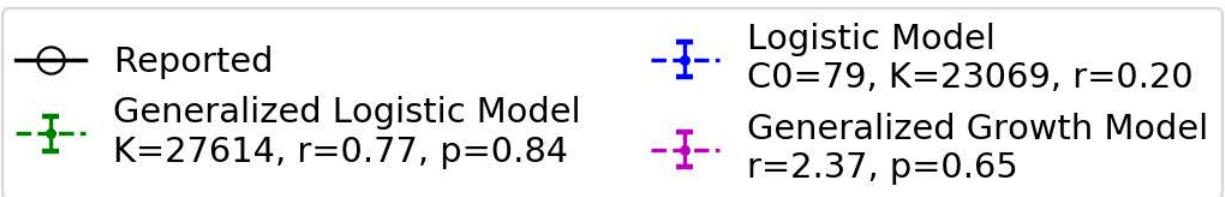
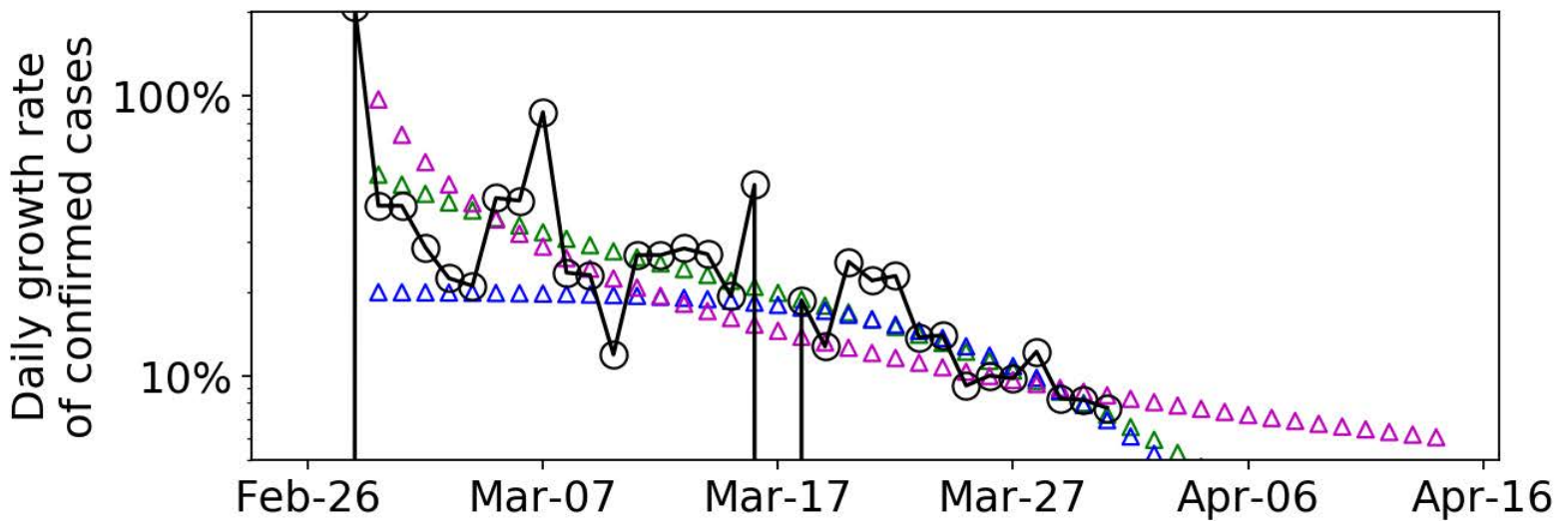
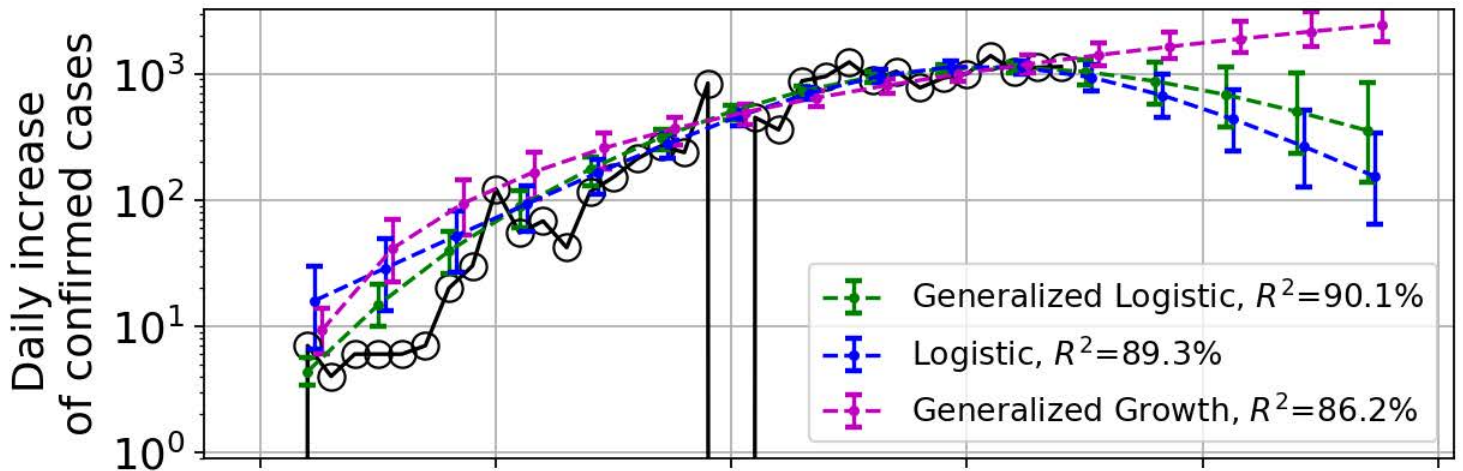
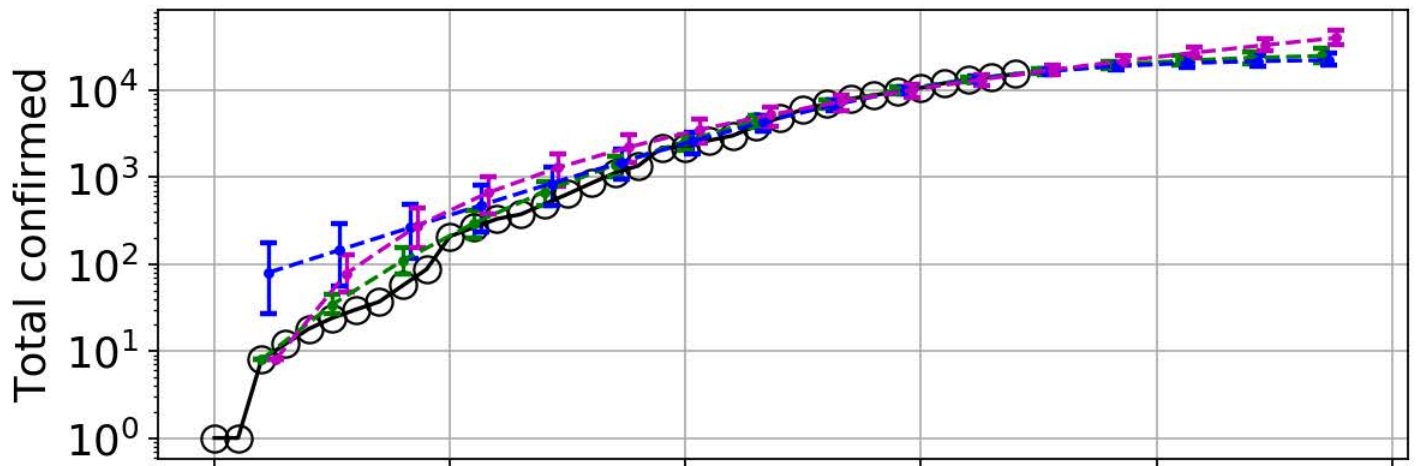
# Iran



# United Kingdom

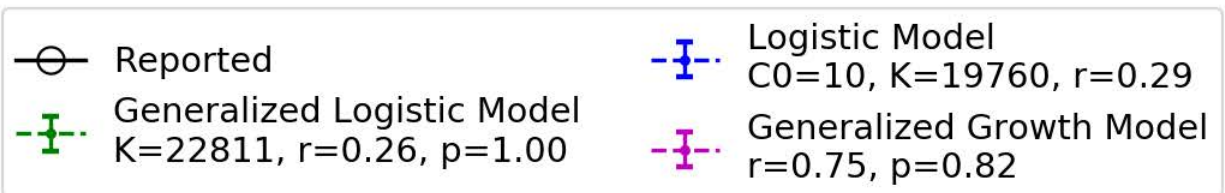
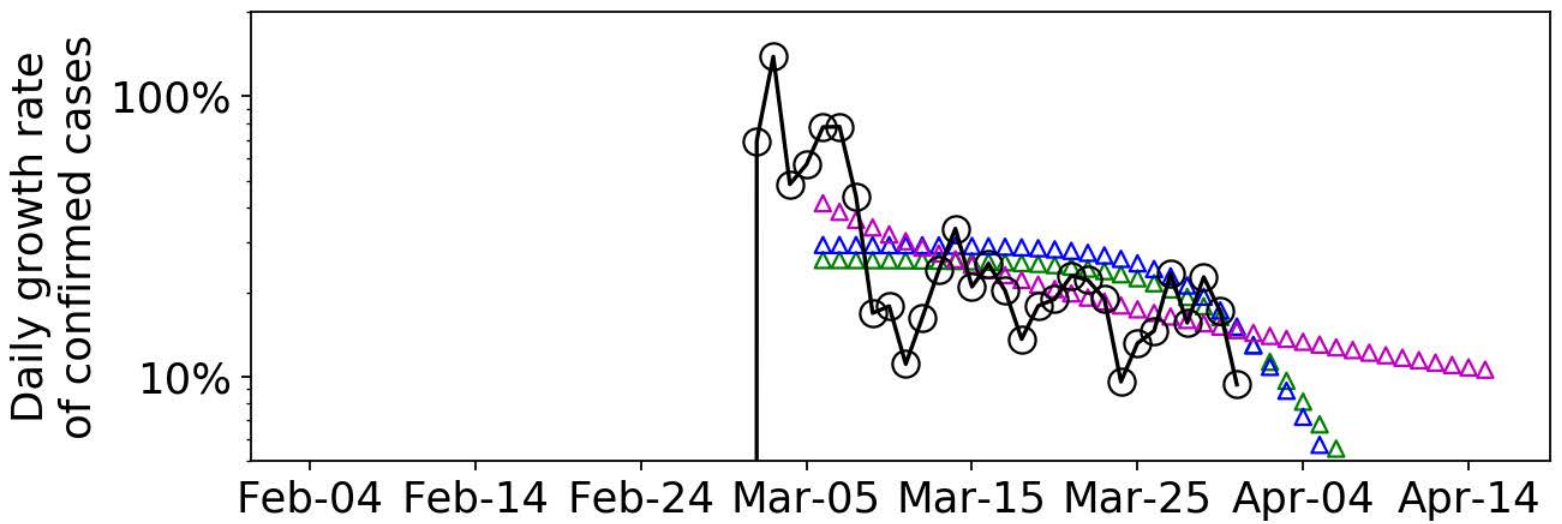
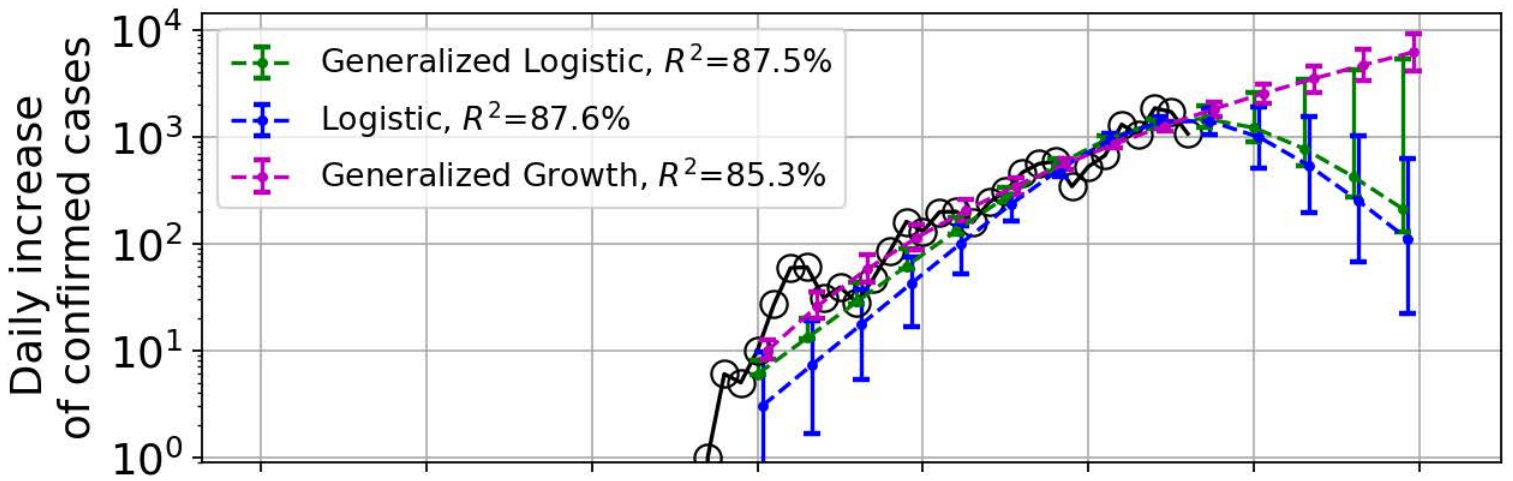
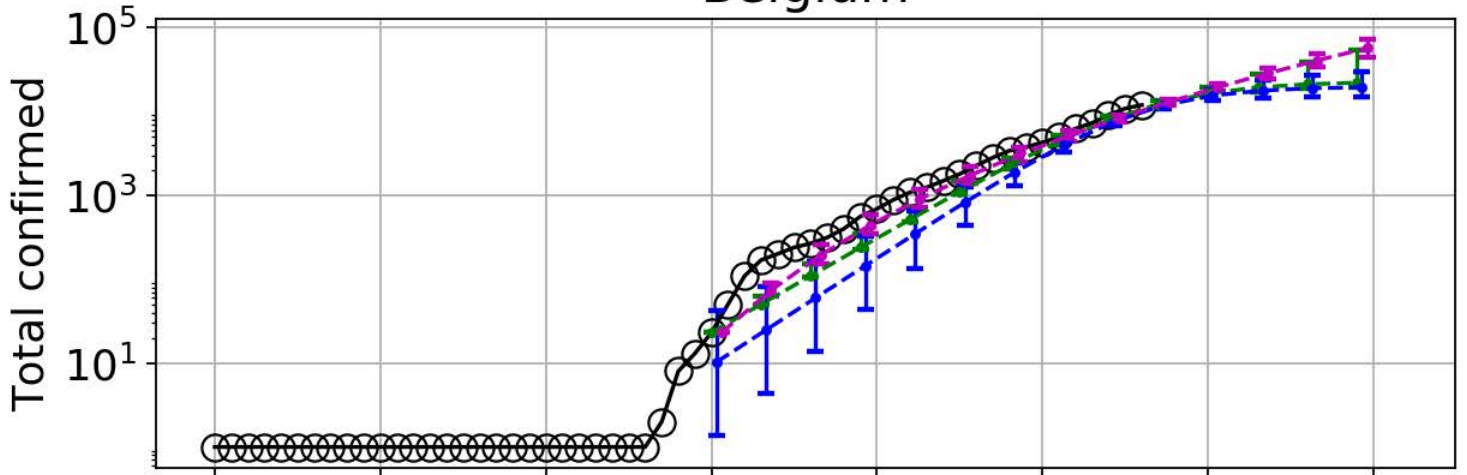


# Switzerland

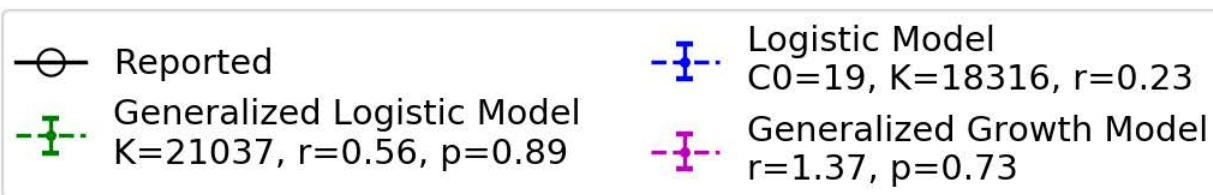
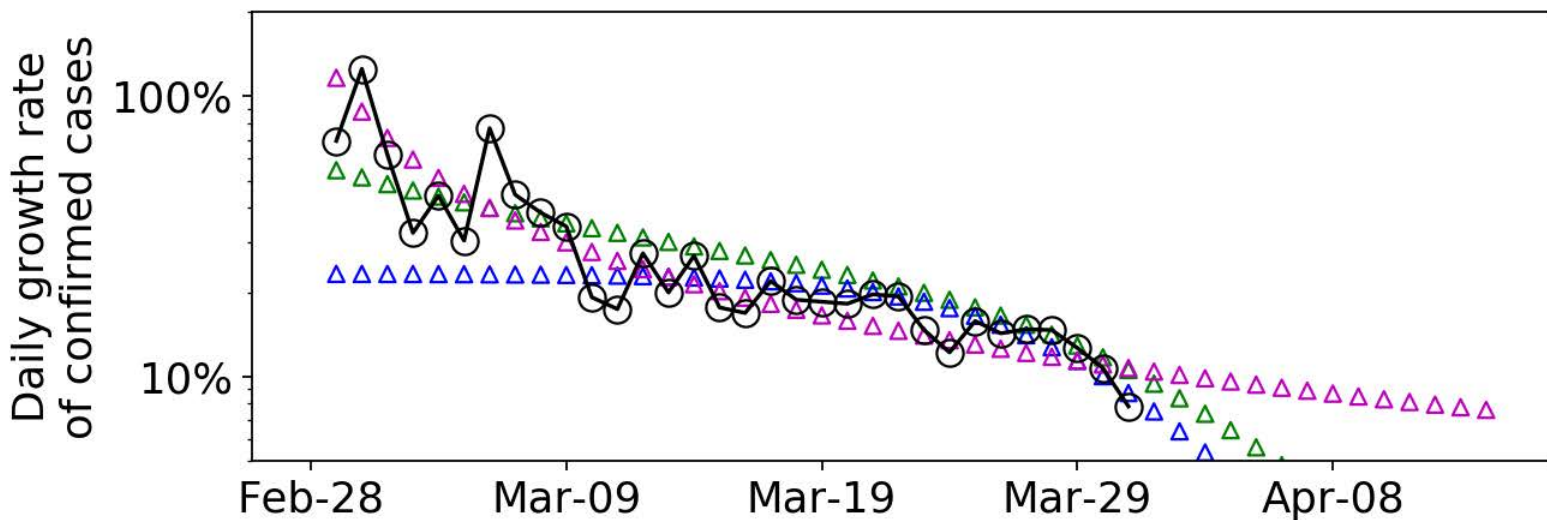
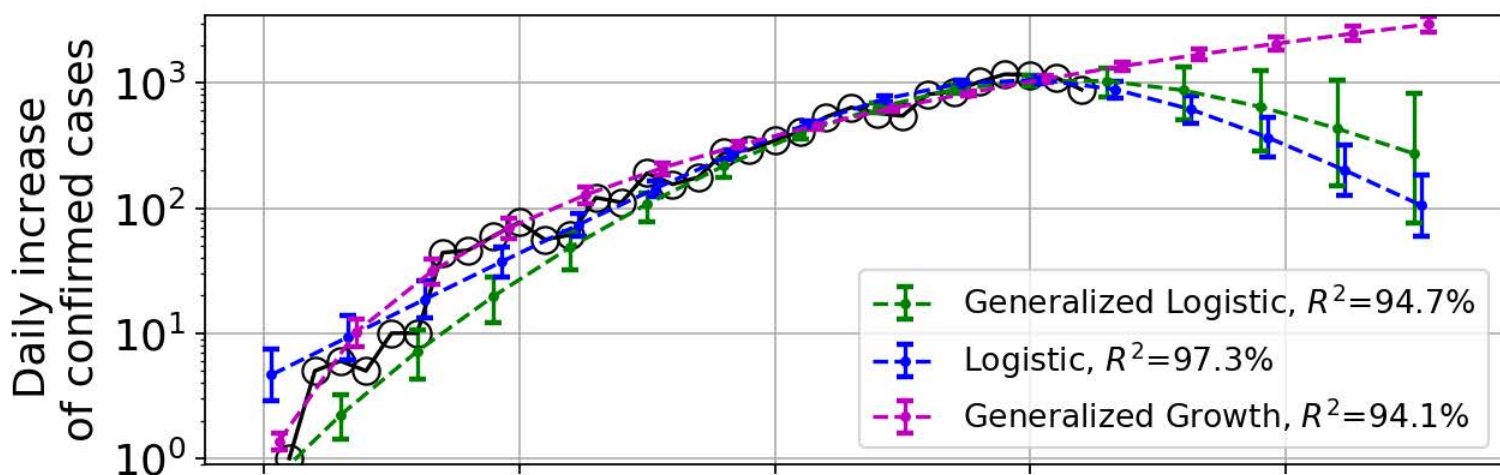
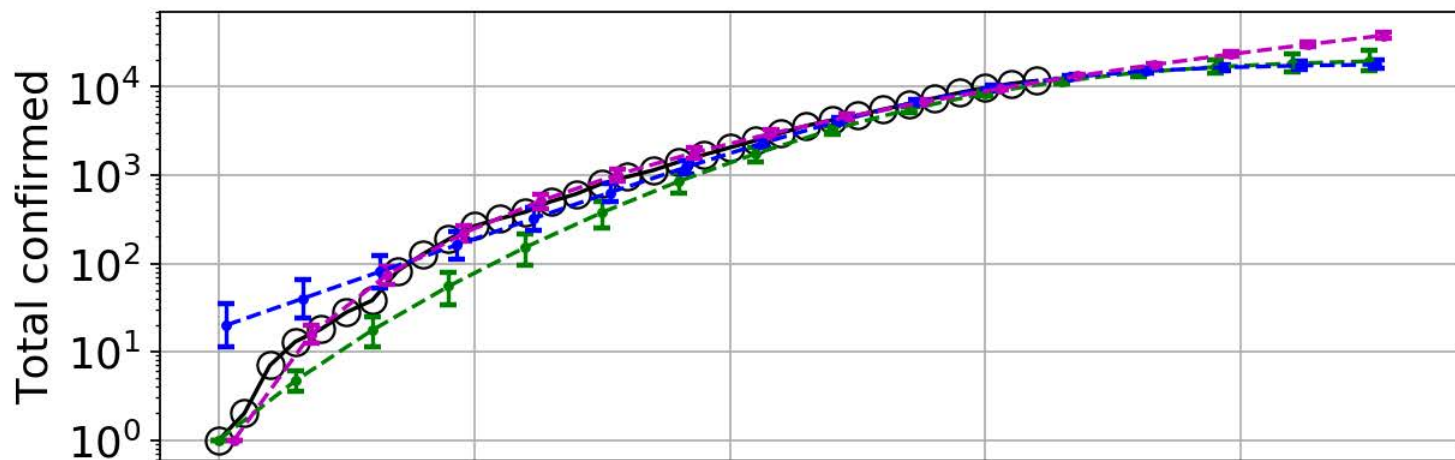




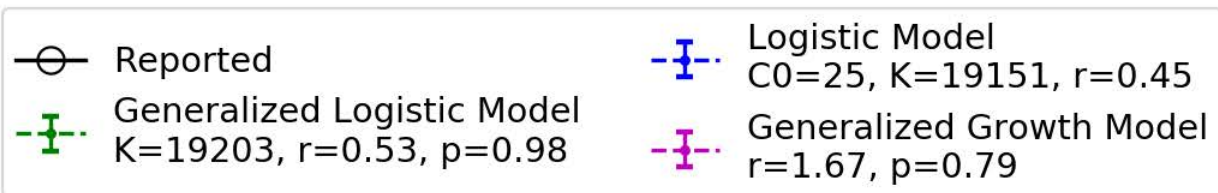
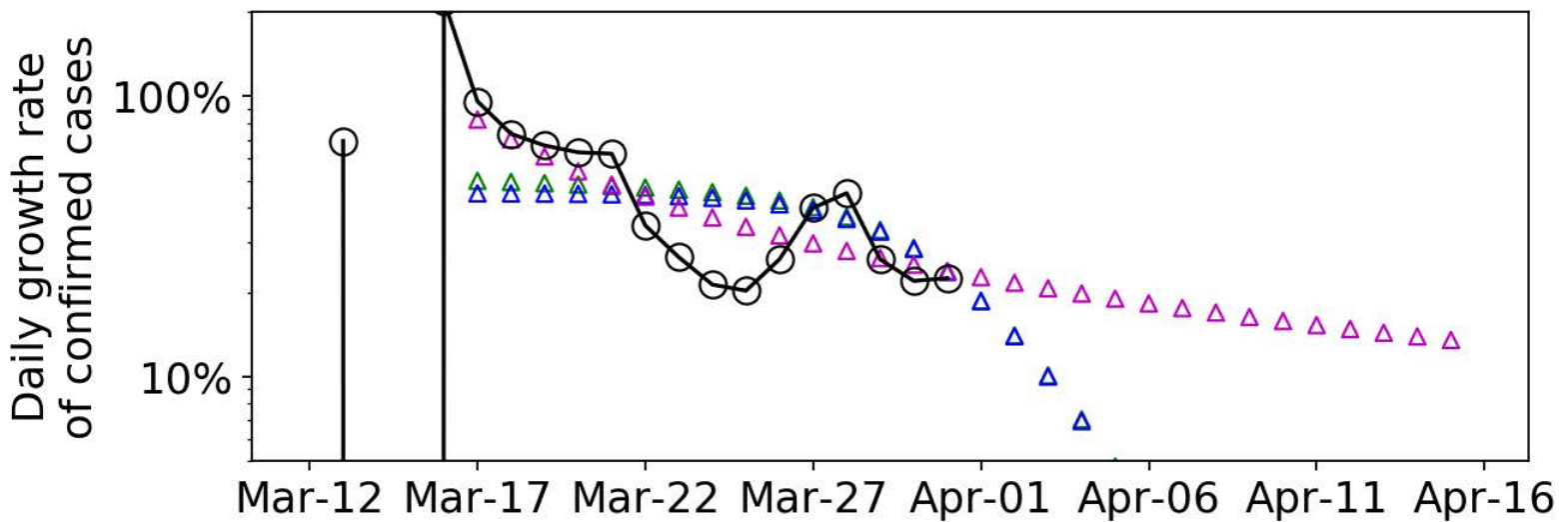
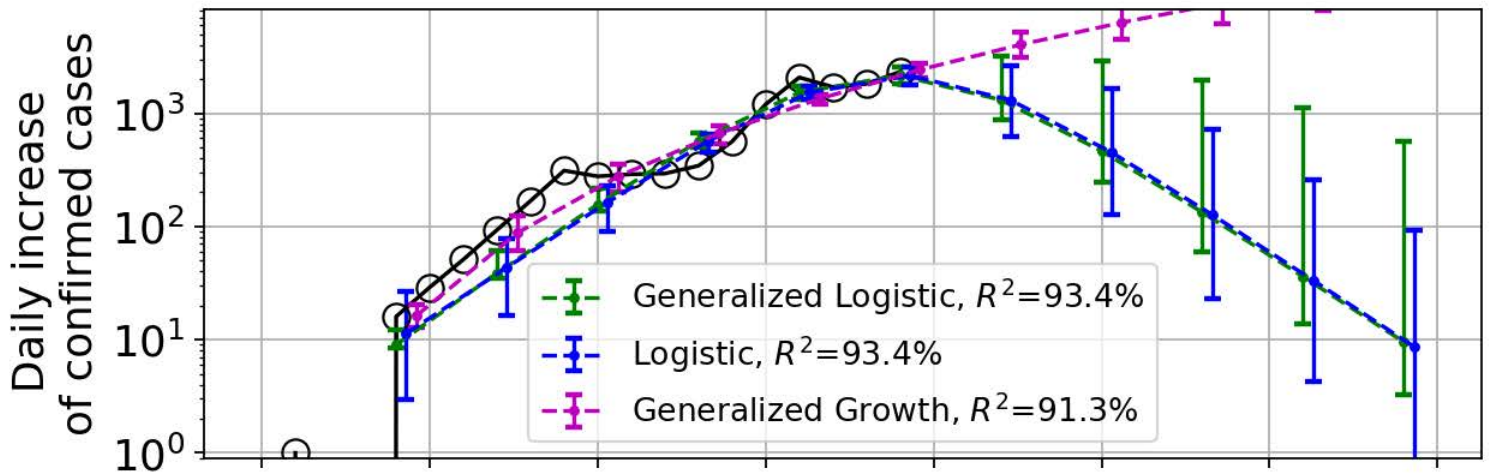
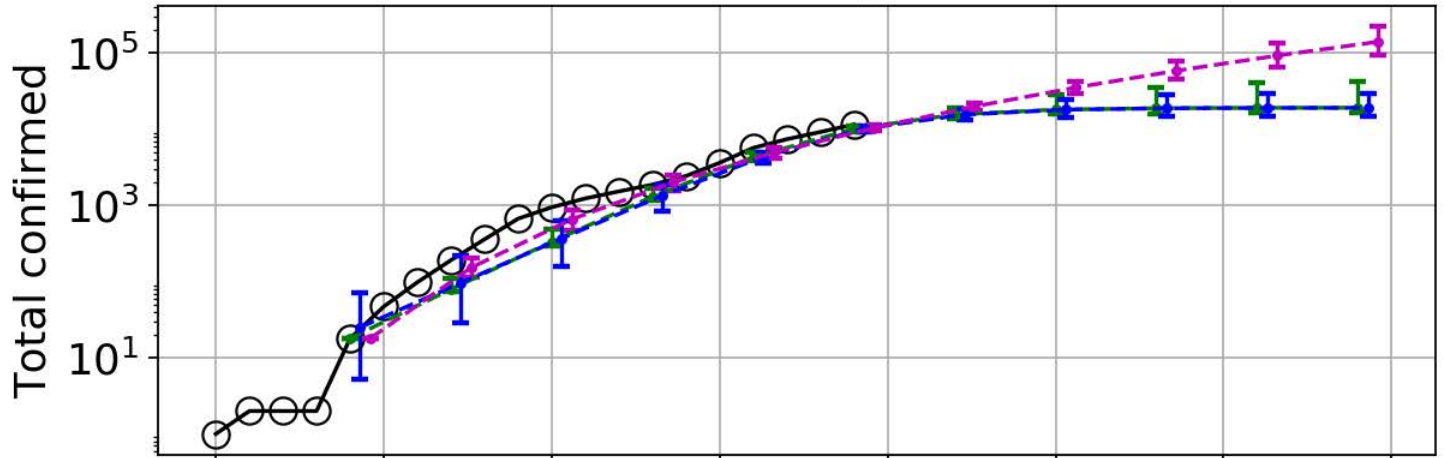
# Belgium



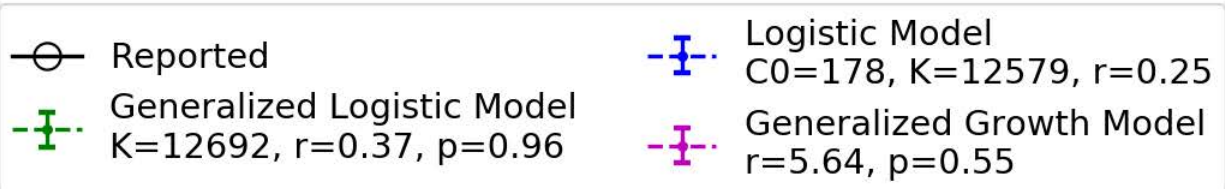
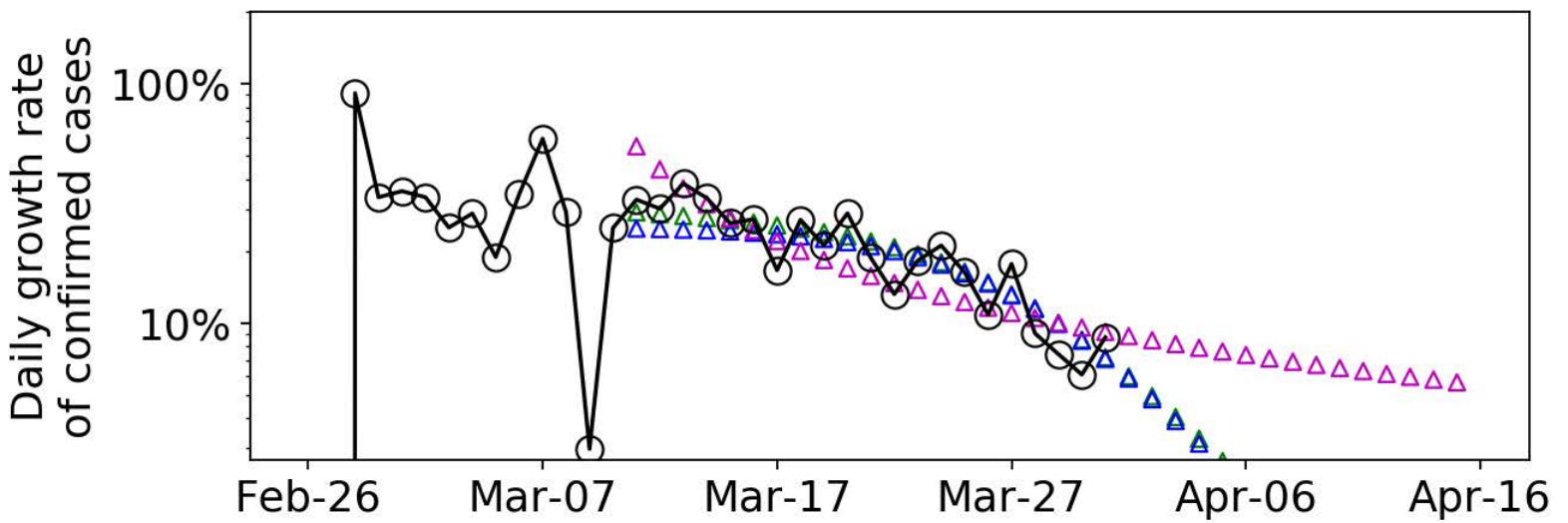
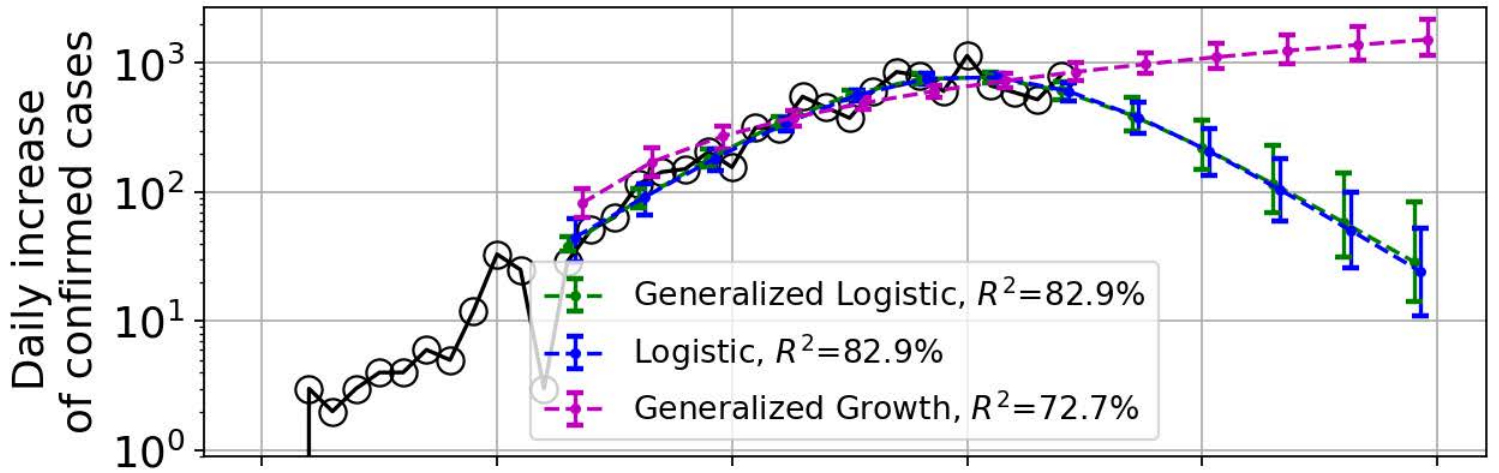
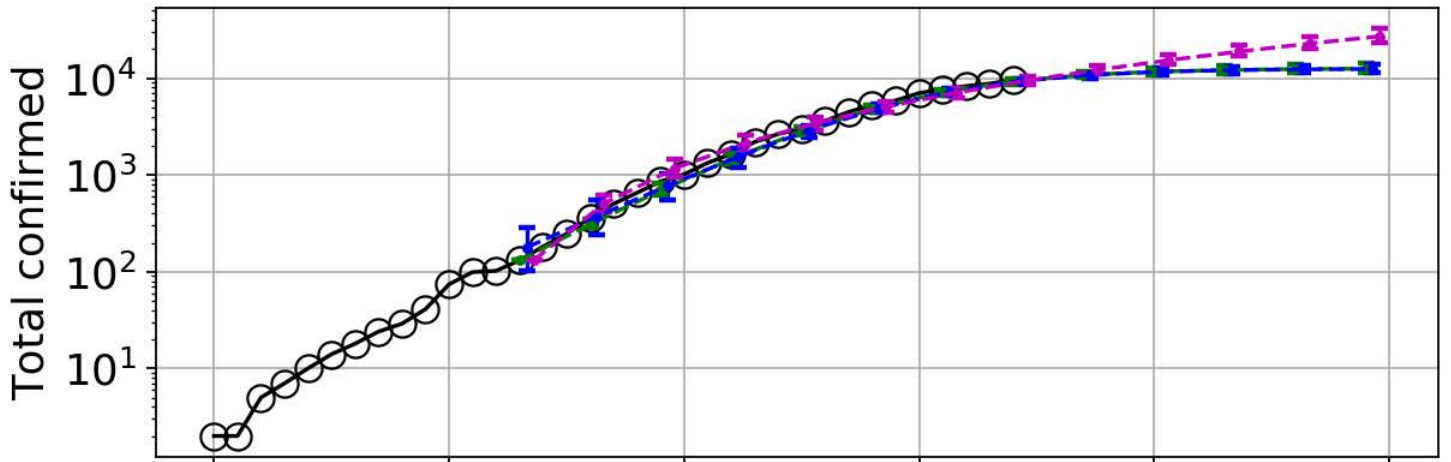
# Netherlands



# Turkey



# Austria



# Japan

