

COVID-19 Confirmed Cases Prediction as of April 6, 2020

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¹ Chair of Entrepreneurial Risks, D-MTEC, ETH Zurich

² Institute of Risk Analysis, Prediction and Management (Risks-X), Academy of Interdisciplinary and Advanced Studies, Southern University of Science and Technology (SUSTech)

³ Gavekal Intelligence Software

Contacts:

Dr. Ke WU (kwu@ethz.ch) and Prof. Dr. Didier SORNETTE (dsornette@ethz.ch)

Summary of the situation:

- Europe records a 5.3% growth rate of confirmed infections today compared with 7.6% yesterday, with outbreak progress in medium scenario rising from 52.6% to 62.6%. The inflection point of Europe is still unclear, but the long tail in the estimated distribution of final number of total confirmed cases per million yesterday disappeared, and the range goes back to 1000-2000 per million population (i.e., 0.1% to 0.2%). It is important to understand that confirmed infections undershoot actual infections by a very large margin.

- The situation in the US continues to be uncertain and we do not expect a quick convergence because the epidemic in the USA is both geographically diverse and at an early stage. The number of tests per million population has risen from 4100 three days ago to 5471 today. Readers can refer to Supplements to COVID-19 Confirmed Cases Prediction (April 1st, 2020)¹ for our analysis on the US test numbers and the confirmed case numbers.

- The daily confirmed cases in Austria continues to decrease (growth rate 1.8%, down from 2.1% yesterday), as nicely projected by the two Logistic growth models (see the detailed plots of Austria at page 20 of the set of figures showing the time dynamics for each country). This confirms that Logistic models become more reliable when the curve is past its inflection point².

- Spain, Switzerland, Belgium, Italy, Germany, Portugal, and France are developing signs that inflection points have been passed, with decreasing growth rate and converged (but sometimes dispersed) distributions of the final confirmed cases. However, more data is needed to confirm that the epidemic is in an after-peak trajectory and it is still possible that they may resume their previous exponential growth, while the warmer weather may make this scenario less likely. Netherlands records a new high in daily confirmed cases today, indicating uncertain future scenarios. Confirmed cases are a leading indicator while deaths are a lagging indicator and we anticipate that daily mortality numbers may begin to fall ~ 2 to 3 weeks after the peak in new confirmed cases.

- UK, Turkey and Japan continue their previous exponential growth, indicating highly uncertain future scenarios, as shown by their non-converged ensemble distributions of final confirmed cases (Figure 1). Yesterday's predictions for UK, Japan and Turkey are largely below their numbers today. The transmission in Japan seems to accelerate and so do reported deaths. Unraveling the epidemic in Japan remains a work in progress.

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

¹https://ethz.ch/content/dam/ethz/special-interest/mtec/chair-of-entrepreneurial-risks-dam/documents/Covid-19/Covid_Supplements_1April2020.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.

Method:

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.-













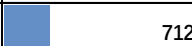
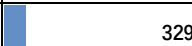
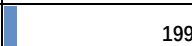
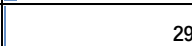
-In Figure 1, we present a distribution of the estimated final total confirmed numbers per million population based on the positive and medium scenario.

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

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

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

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

	Confirmed per Million Population (Apr-06)	Outbreak Progress in Positive Scenario	Outbreak Progress in Medium Scenario	Tests per Million Population (update date in brackets)	Confirmed Cases per Test (update date in brackets)
Spain	 2799	90.0% (85.3%, 95.5%)	74.0% (69.1%, 79.3%)	7596 (Mar 21)	5.6% (Mar 21)
Switzerland	 2473	84.2% (76.1%, 92.9%)	73.2% (63.5%, 81.6%)	17904 (Apr 04)	12.8% (Apr 04)
Italy	 2134	Not reliable	77.0% (72.4%, 81.8%)	10896 (Apr 04)	18.2% (Apr 04)
Belgium	 1724	68.9% (58.9%, 78.5%)	66.6% (51.3%, 77.6%)	1594 (Mar 18)	6.8% (Mar 18)
Austria	 1354	92.4% (86.9%, 98.0%)	92.1% (87.5%, 97.9%)	12502 (Apr 06)	10.8% (Apr 06)
Germany	 1150	75.1% (68.6%, 80.9%)	68.5% (60.3%, 76.3%)	11046 (Mar 29)	5.7% (Mar 29)
Portugal	 1097	73.0% (65.2%, 80.9%)	70.1% (58.5%, 79.1%)	5068 (Mar 31)	12.3% (Mar 31)
France	 1052	79.2% (70.4%, 88.4%)	78.4% (65.8%, 89.0%)	3346 (Apr 02)	25.4% (Apr 02)
Netherlands	 1036	85.3% (79.0%, 91.3%)	63.6% (54.9%, 71.0%)	4328 (Apr 02)	18.1% (Apr 02)
United States	 1032	58.7% (45.4%, 68.5%)	52.4% (40.3%, 62.2%)	5471 (Apr 05)	17.4% (Apr 05)
Europe	 866	72.1% (67.1%, 76.3%)	62.6% (57.1%, 67.5%)	NA	NA
United Kingdom	 719	33.9% (11.3%, 50.5%)	22.6% (0.0%, 42.3%)	2895 (Apr 05)	21.4% (Apr 05)
Iran	 712	Not reliable	Not reliable	962 (Mar 22)	25.8% (Mar 22)
Turkey	 329	65.2% (52.6%, 75.5%)	40.3% (9.3%, 60.1%)	2182 (Apr 05)	13.2% (Apr 05)
South Korea	 199	Not reliable	Not reliable	8920 (Apr 05)	2.2% (Apr 05)
Japan	 29	4.0% (0.0%, 36.3%)	0.0% (0.0%, 17.0%)	366 (Apr 06)	7.9% (Apr 06)

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?

Ensemble Distribution of Final Confirmed Cases per Million Population

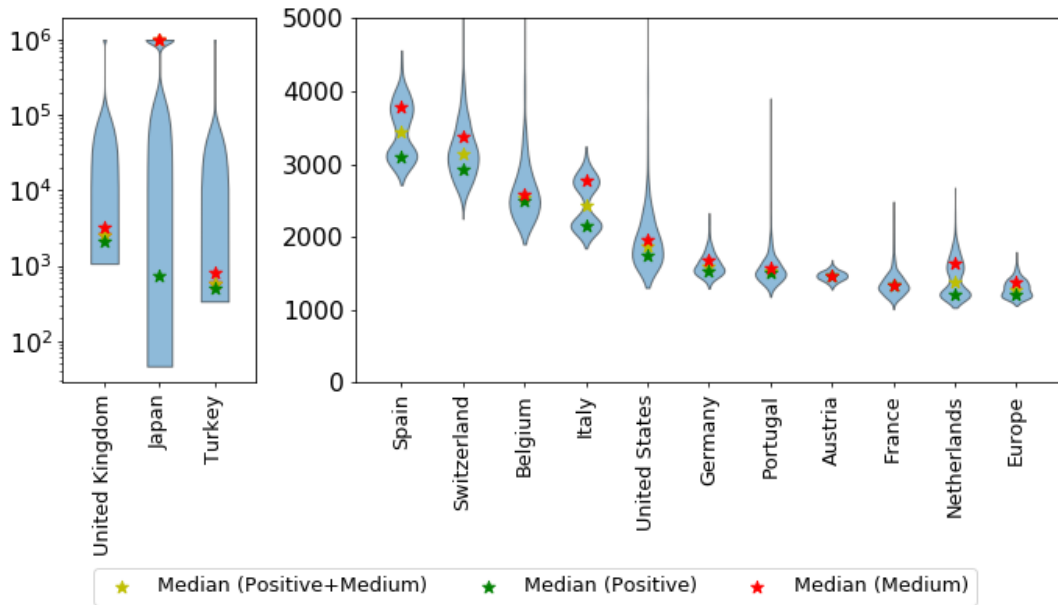


Figure 1. Violin plot of the distributions of the final total number of confirmed cases per million derived by combining the distributions of the positive and medium scenarios. The model setup in the negative scenario does not incorporate a maximum saturation number and thus cannot be used. The yellow 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).

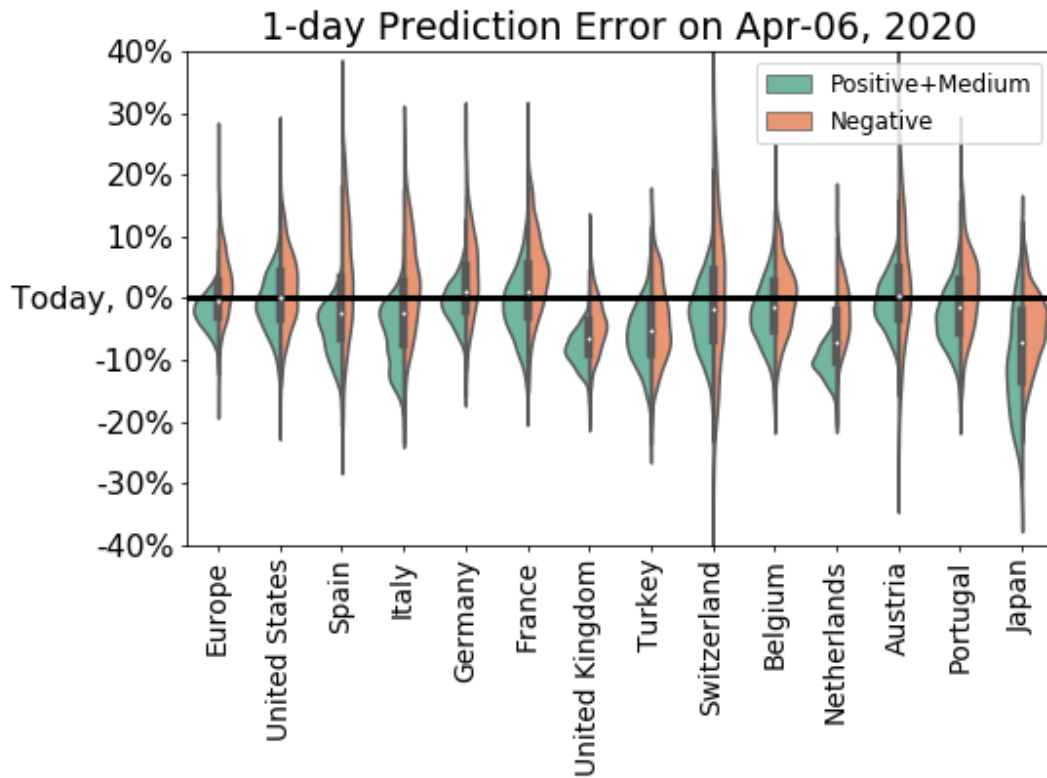


Figure 2. One-day prediction error of the 13 countries/regions. The horizontal line corresponds to today's empirical data. We show the full distribution of errors for each of the two scenarios.

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	7-Apr	11-Apr	16-Apr	Final Total Confirmed
Europe	Positive	(603, 647) 646	659 (637, 679)	759 (730, 789)	834 (797, 878)	896 (846, 963)
	Medium	(620, 658) 646	665 (649, 682)	785 (760, 809)	890 (852, 934)	1030 (957, 1130)
	Negative	(621, 705) 646	695 (646, 752)	900 (834, 976)	1210 (1100, 1340)	Not Reliable
United States	Positive	(311, 359) 338	357 (337, 377)	454 (418, 498)	525 (466, 617)	575 (493, 743)
	Medium	(317, 352) 338	357 (341, 370)	464 (434, 495)	557 (500, 627)	645 (543, 838)
	Negative	(316, 369) 338	373 (335, 410)	549 (490, 614)	843 (734, 990)	Not Reliable
Spain	Positive	(114, 126) 131	125 (119, 131)	137 (130, 144)	143 (135, 150)	145 (137, 153)
	Medium	(124, 133) 131	134 (129, 138)	152 (146, 158)	166 (157, 174)	177 (165, 189)
	Negative	(119, 153) 131	141 (122, 164)	184 (159, 214)	251 (209, 300)	Not Reliable
Italy	Positive	(110, 122) 129	118 (112, 124)	125 (118, 131)	128 (121, 135)	130 (122, 138)
	Medium	(122, 131) 129	131 (127, 135)	143 (138, 148)	153 (147, 159)	168 (158, 178)
	Negative	(119, 146) 129	135 (122, 149)	162 (146, 178)	199 (178, 219)	Not Reliable
Germany	Positive	(89.8, 98.8) 95.4	97.9 (93.7, 103)	111 (106, 118)	120 (113, 129)	127 (118, 139)
	Medium	(91.4, 99.7) 95.4	98.2 (94.3, 102)	114 (108, 119)	126 (117, 135)	139 (125, 158)
	Negative	(91.2, 108) 95.4	103 (93.8, 114)	134 (121, 149)	179 (159, 204)	Not Reliable
France	Positive	(64.9, 75.1) 70.5	70.6 (65.6, 76)	79.8 (73.4, 86.9)	85.7 (77.4, 94.4)	89 (79.7, 100)
	Medium	(64.5, 74) 70.5	69.5 (65, 75.2)	79.4 (73, 86.6)	85.7 (77.2, 96.3)	89.8 (79.2, 107)
	Negative	(67.5, 79.8) 70.5	75.6 (67.6, 84.7)	98 (87.4, 110)	131 (116, 149)	Not Reliable
United Kingdom	Positive	(42.1, 46) 47.8	51.5 (48.5, 54.8)	74.5 (66.7, 84.4)	101 (81.8, 138)	141 (94.7, 422)
	Medium	(42.1, 45.6) 47.8	51 (48.8, 53.1)	75.6 (69.1, 82.6)	110 (89.8, 140)	Not Reliable
	Negative	(43, 48.5) 47.8	51.7 (48.9, 54.6)	80.8 (76, 85.8)	135 (123, 150)	Not Reliable
Turkey	Positive	(23.5, 27) 27.1	28 (26, 29.7)	35.9 (32.5, 39.8)	39.9 (35.1, 47.4)	41.5 (35.9, 51.5)

	Medium	(23.9, 27.3) 27.1	28.8 (27, 30.7)	40.7 (35.9, 46.1)	52.3 (41.5, 71.8)	67.2 (45.1, 292)
	Negative	(23.9, 28.6) 27.1	29.5 (27, 31.9)	46.4 (42.2, 51.1)	75.2 (65.9, 87.4)	Not Reliable
Switzerland	Positive	(19.3, 22.3) 21.1	21.4 (19.9, 23)	23.2 (21.4, 25.1)	24.3 (22.2, 26.5)	25 (22.7, 27.7)
	Medium	(20.3, 23.3) 21.1	22.2 (20.7, 23.8)	24.7 (22.9, 26.6)	26.6 (24.5, 29.1)	28.8 (25.8, 33.2)
	Negative	(19.1, 26.3) 21.1	22.9 (19.6, 27.1)	28.3 (24, 33.6)	36.4 (30, 43.5)	Not Reliable
Belgium	Positive	(18, 20.6) 19.7	20.5 (19.1, 21.8)	24.4 (22.3, 26.4)	26.8 (24.1, 30.2)	28.6 (25.1, 33.4)
	Medium	(17.9, 20.3) 19.7	20.2 (19, 21.4)	24.2 (22.4, 26.3)	27.1 (24.3, 31.4)	29.6 (25.4, 38.4)
	Negative	(18.2, 21.4) 19.7	21.1 (19.5, 23)	29.1 (26.5, 31.7)	41.3 (37, 46.8)	Not Reliable
Netherlands	Positive	(16.2, 17.6) 17.9	17.8 (16.9, 18.7)	19.5 (18.4, 20.7)	20.4 (19.2, 21.8)	20.9 (19.5, 22.6)
	Medium	(16.1, 17.5) 17.9	18.3 (17.7, 19)	21.6 (20.6, 22.7)	24.4 (22.9, 26.2)	28.1 (25.2, 32.5)
	Negative	(17.6, 20) 17.9	20.1 (18.8, 21.4)	26.1 (24.4, 27.9)	35.2 (32.4, 37.8)	Not Reliable
Austria	Positive	(11.3, 12.7) 12	12.1 (11.5, 12.8)	12.6 (11.9, 13.4)	12.9 (12.1, 13.7)	13 (12.2, 13.8)
	Medium	(11.2, 12.5) 12	12.1 (11.5, 12.7)	12.6 (12, 13.3)	12.9 (12.2, 13.6)	13 (12.2, 13.7)
	Negative	(10.9, 14) 12	12.5 (10.7, 14.5)	15.1 (12.9, 17.6)	18.7 (15.9, 22.1)	Not Reliable
Portugal	Positive	(10.3, 11.8) 11.3	11.8 (11.1, 12.5)	13.7 (12.7, 14.7)	14.8 (13.6, 16.3)	15.4 (13.9, 17.3)
	Medium	(10.2, 11.5) 11.3	11.7 (10.9, 12.3)	13.7 (12.8, 14.8)	15.1 (13.7, 16.8)	16.1 (14.3, 19.3)
	Negative	(10.4, 12.4) 11.3	12.2 (11.1, 13.2)	16.5 (14.8, 17.9)	22.8 (20.1, 25.6)	Not Reliable
Japan	Positive	(2.78, 3.29) 3.65	3.39 (3.12, 3.66)	5.41 (4.72, 5.99)	9.26 (6.61, 11.6)	Not Reliable
	Medium	(3.21, 3.77) 3.65	3.96 (3.67, 4.25)	5.58 (5.11, 6.09)	8.57 (7.31, 9.68)	Not Reliable
	Negative	(3.18, 3.73) 3.65	3.94 (3.65, 4.25)	5.58 (5.14, 6.1)	8.6 (7.78, 9.66)	Not Reliable
Iran	Positive	(45.3, 54.6) 58.2	52 (47.7, 56.8)	58.5 (52.9, 65)	62.8 (55.9, 72.2)	Not Reliable
	Medium	(55.5, 61.8) 58.2	61.4 (58, 64.7)	74.7 (70.1, 79.6)	93.5 (84.3, 101)	Not Reliable
	Negative	(55.6, 62.6) 58.2	61.8 (58.5, 65.1)	76.1 (71.5, 80.4)	96.4 (90.5, 103)	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.

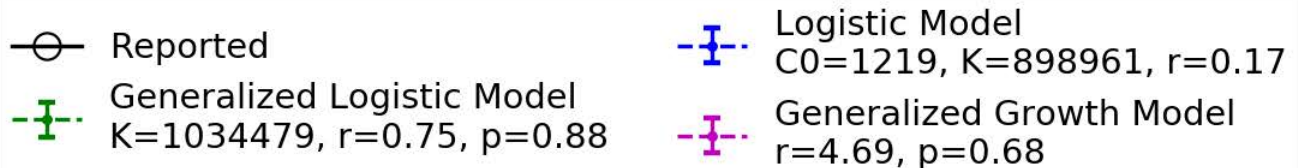
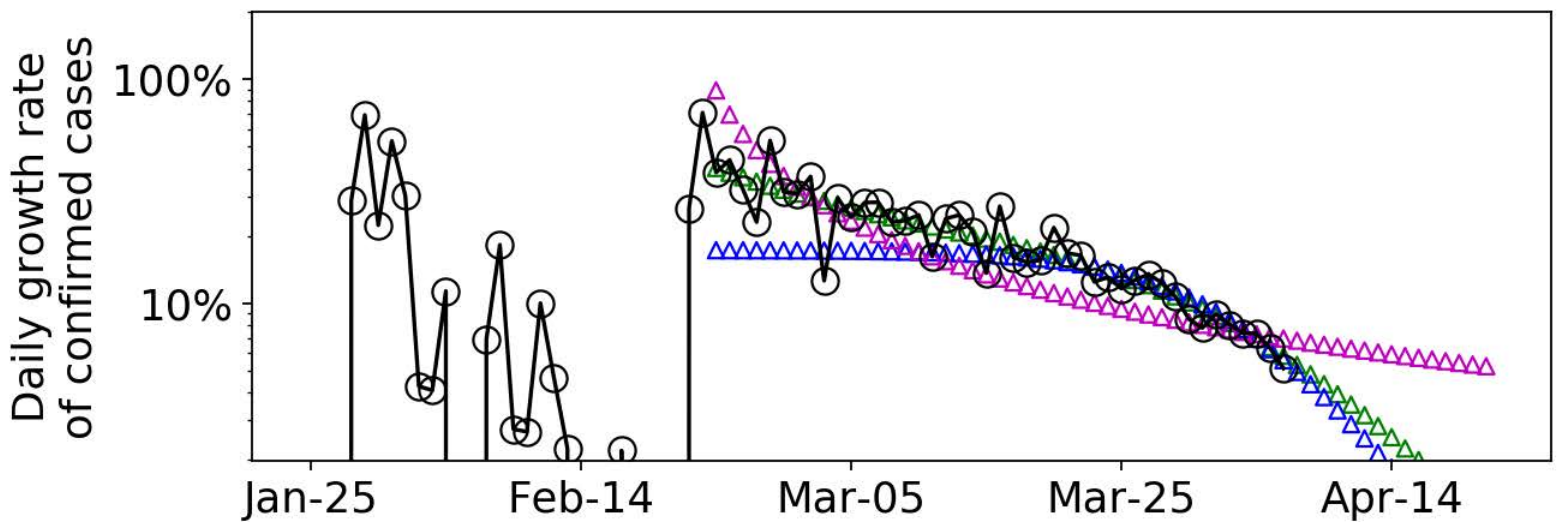
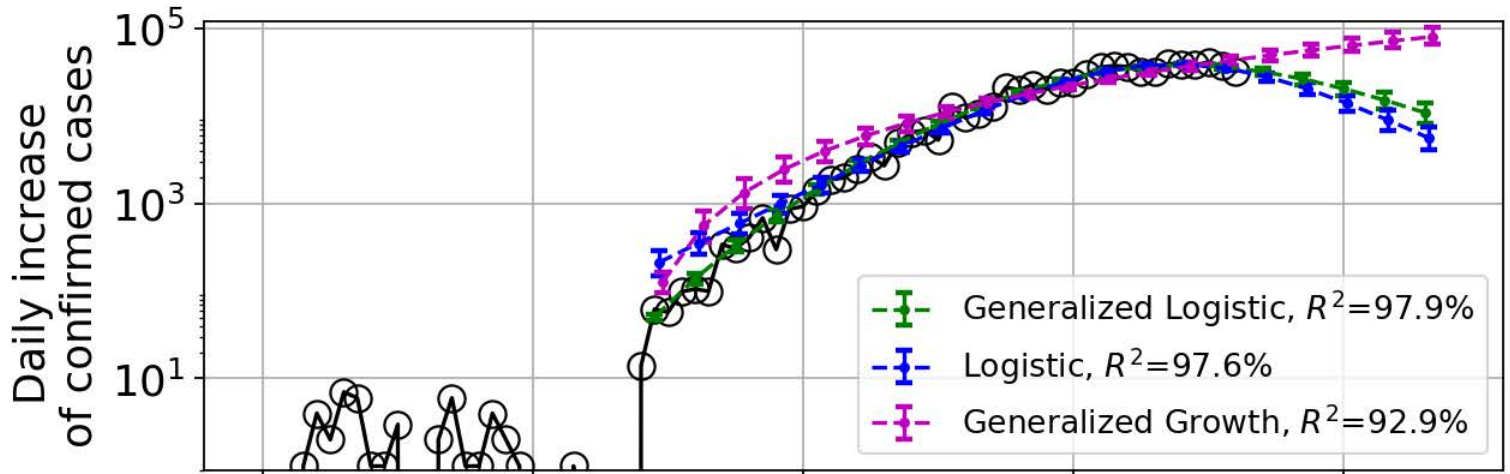
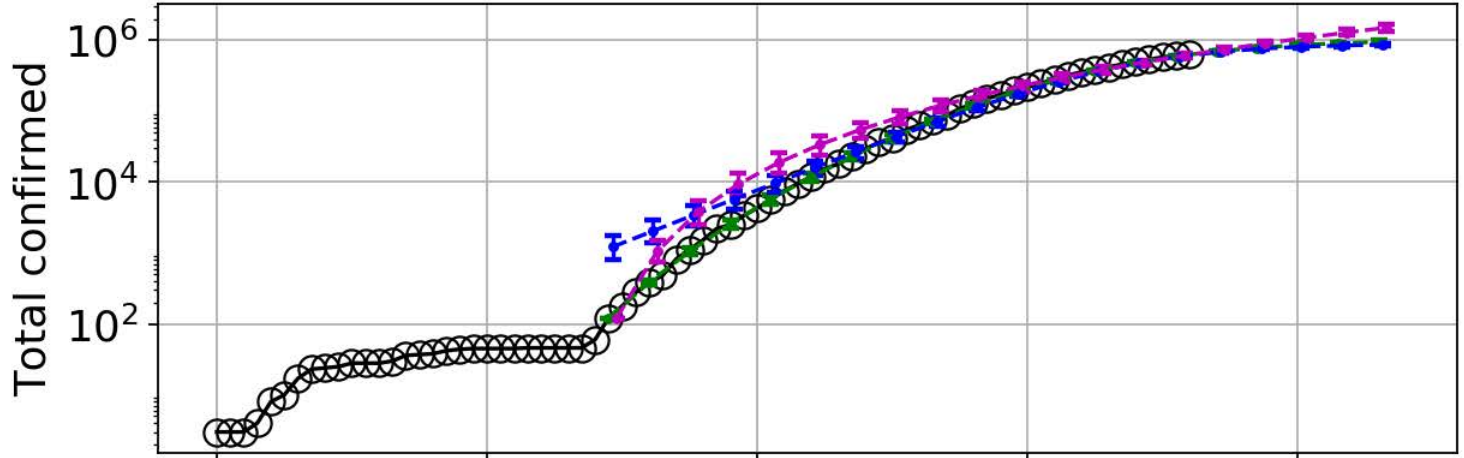
We anticipate that, over time, our methodology will improve and will provide a more accurate picture of the true levels of infection and where they are headed.

[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>

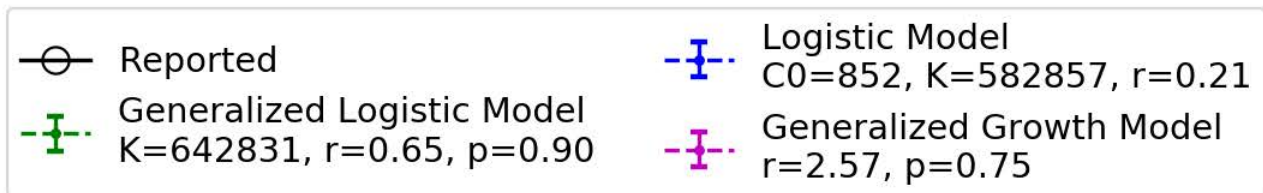
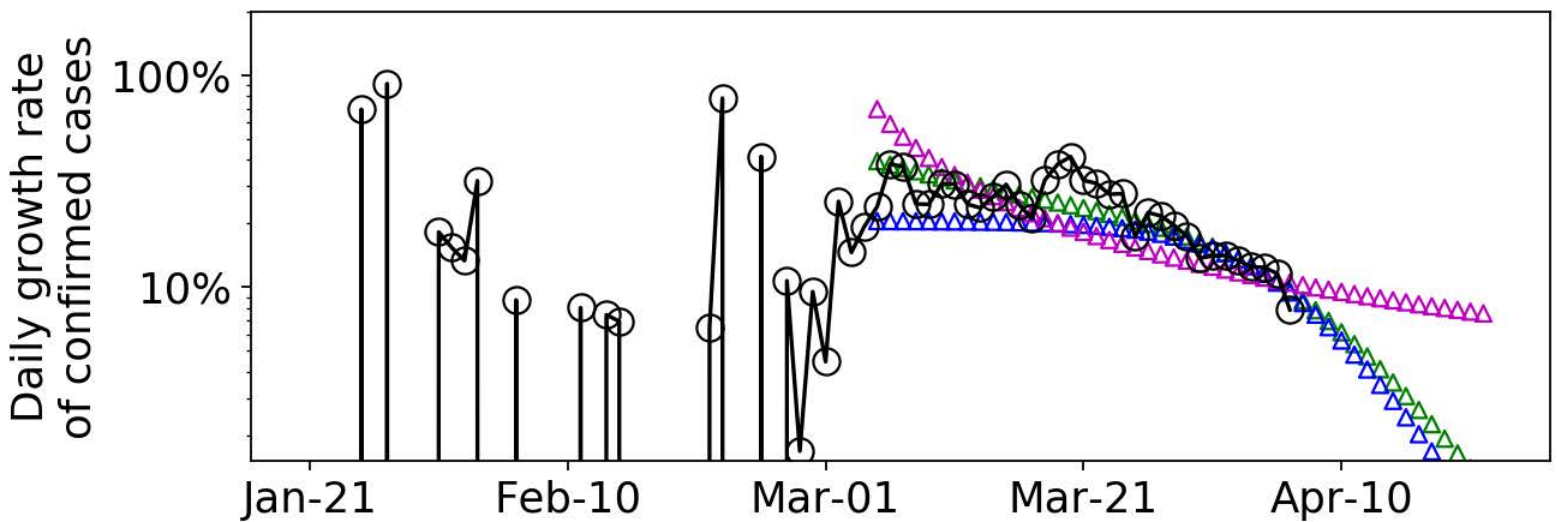
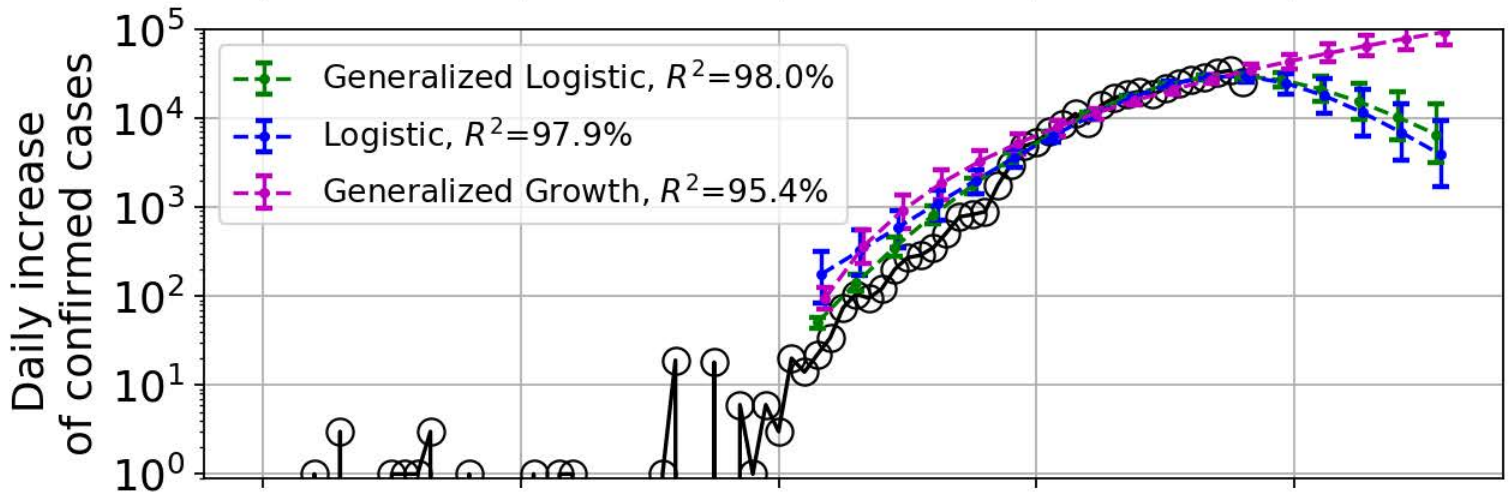
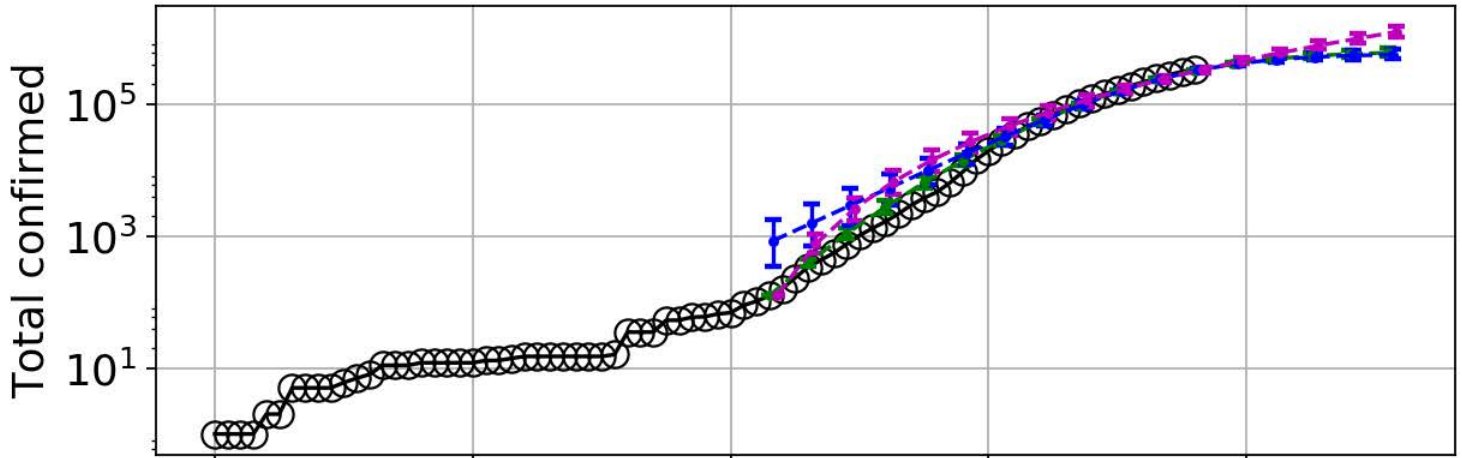
[2] <https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases>

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

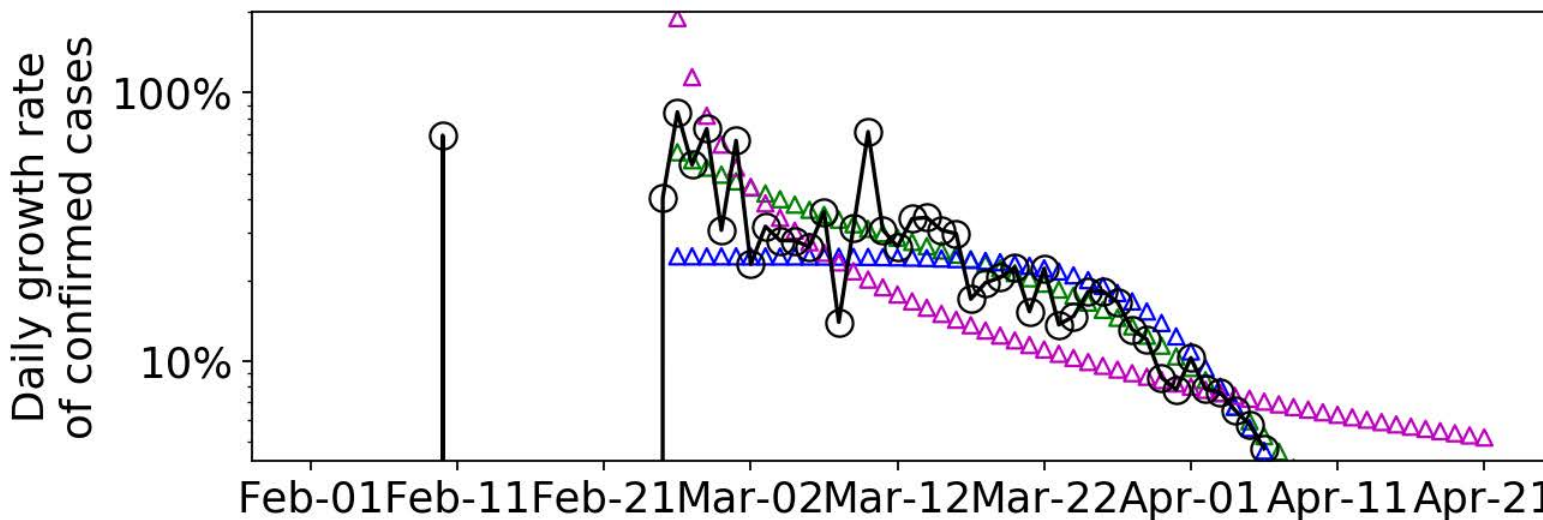
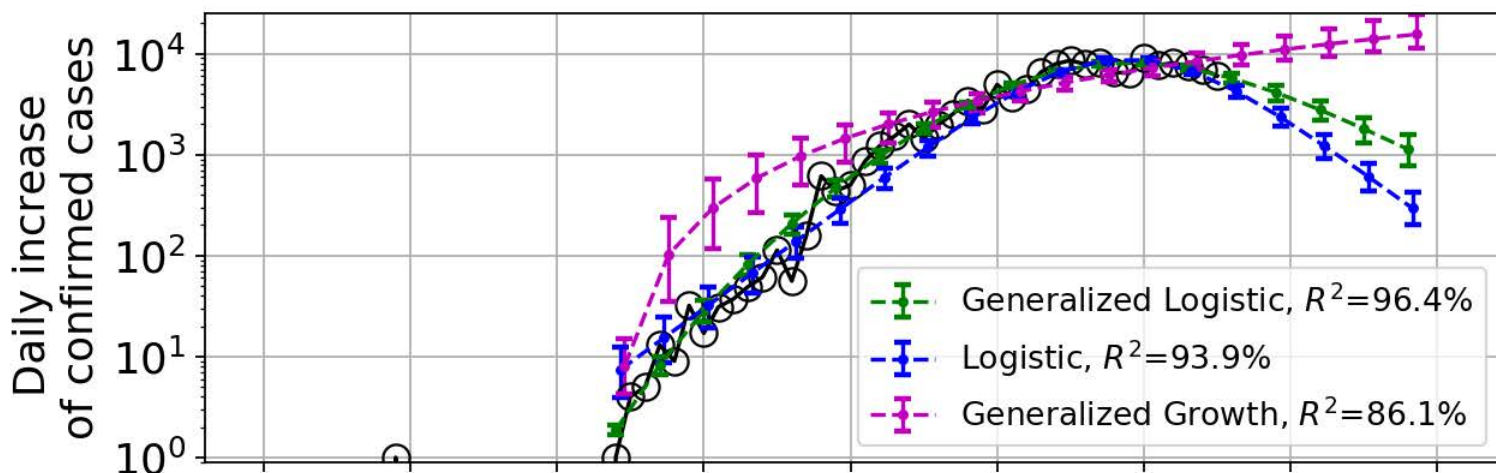
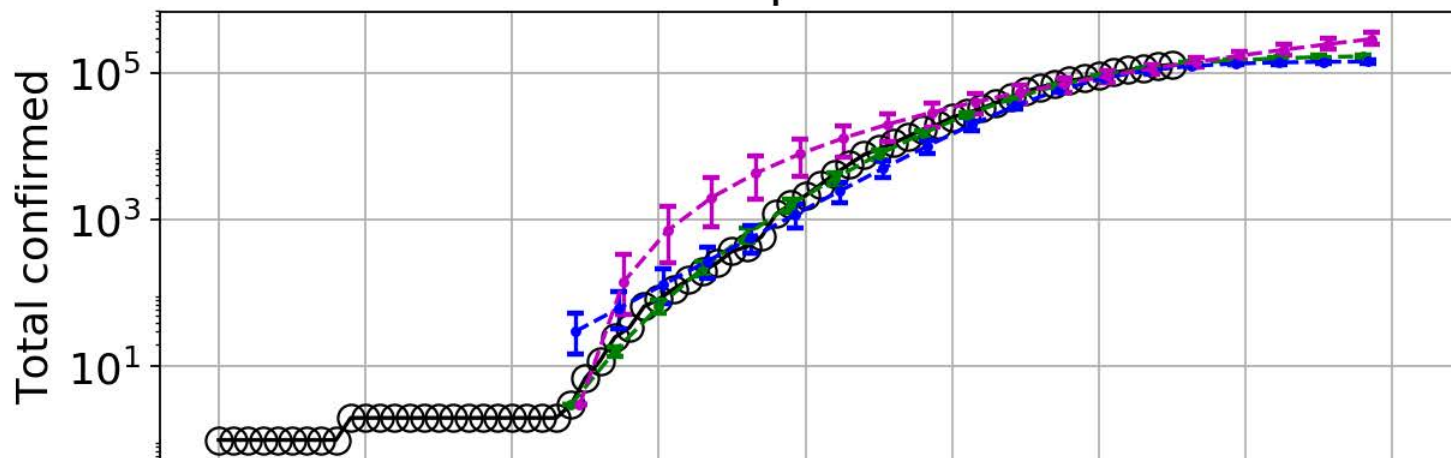
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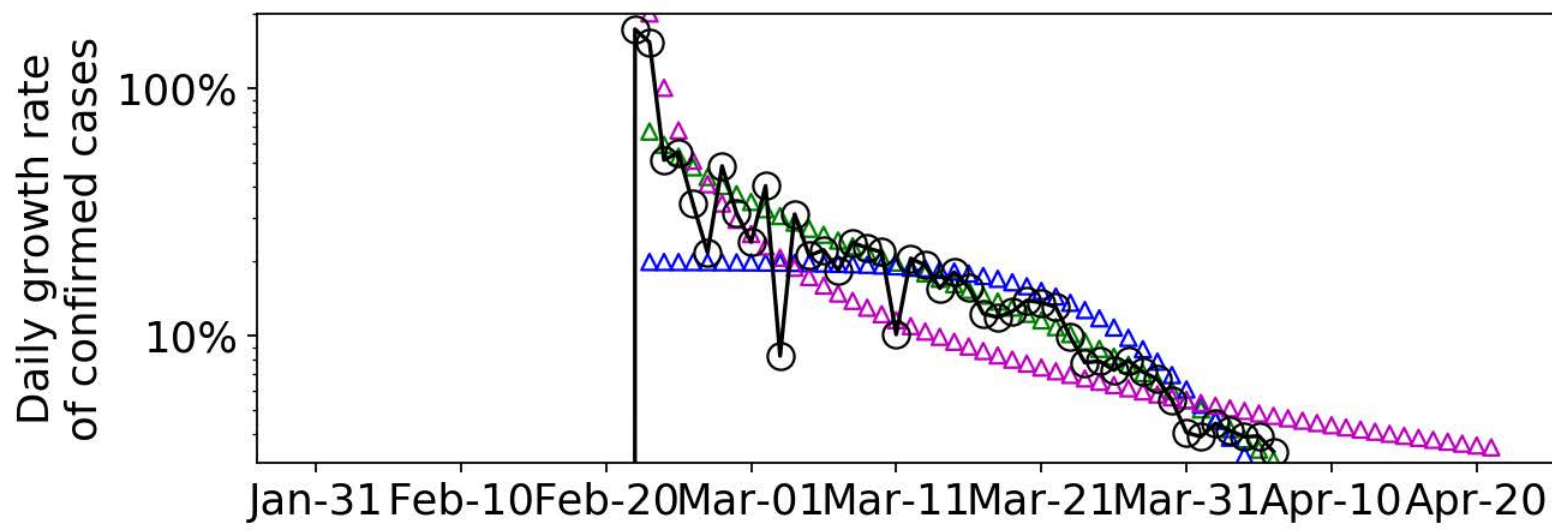
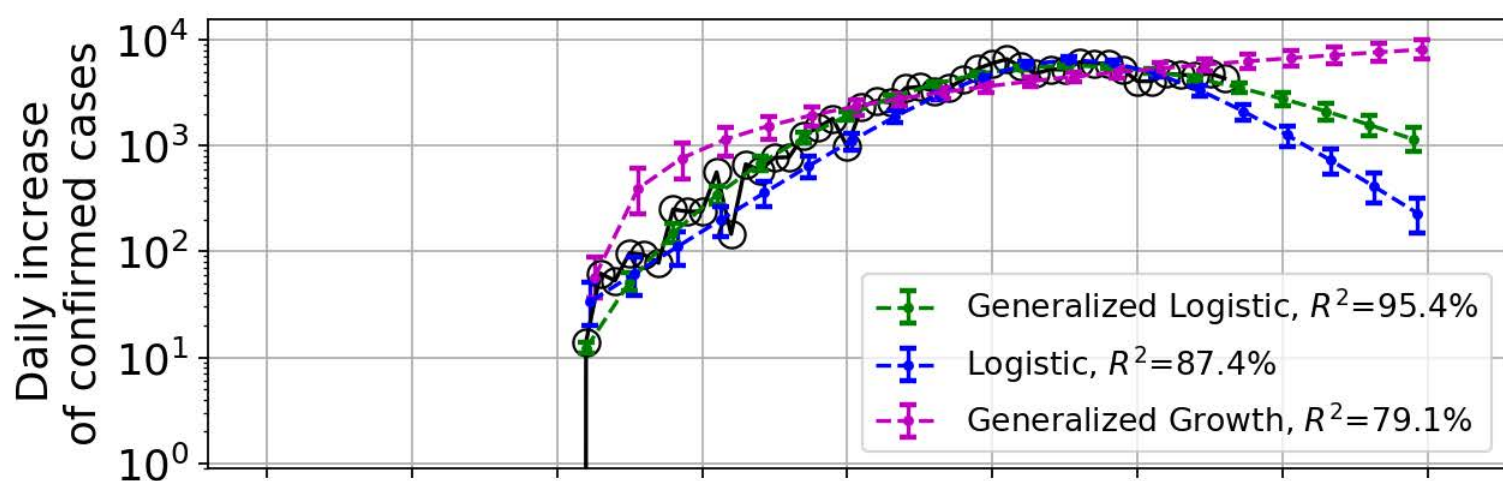
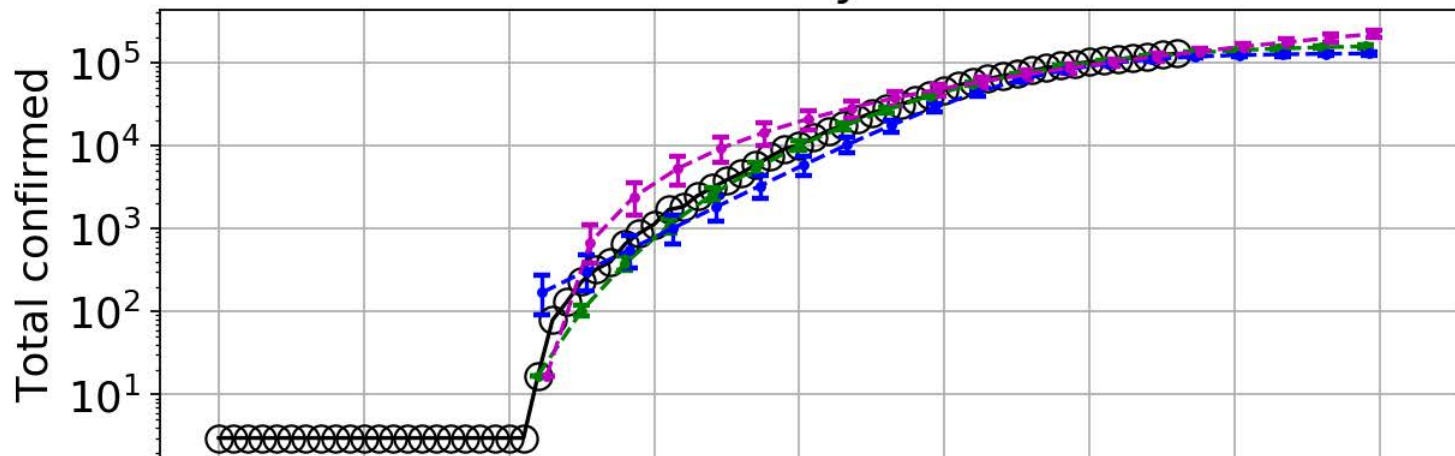
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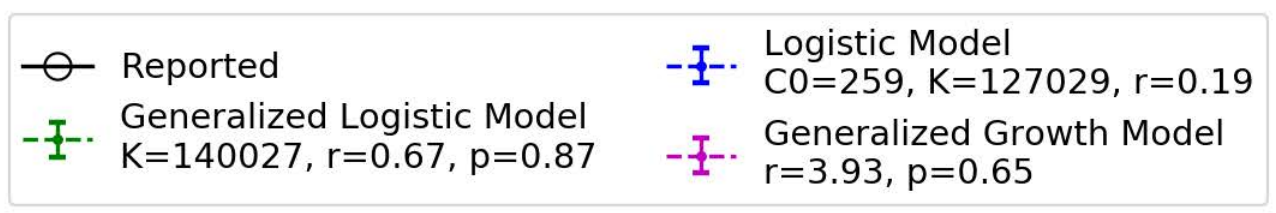
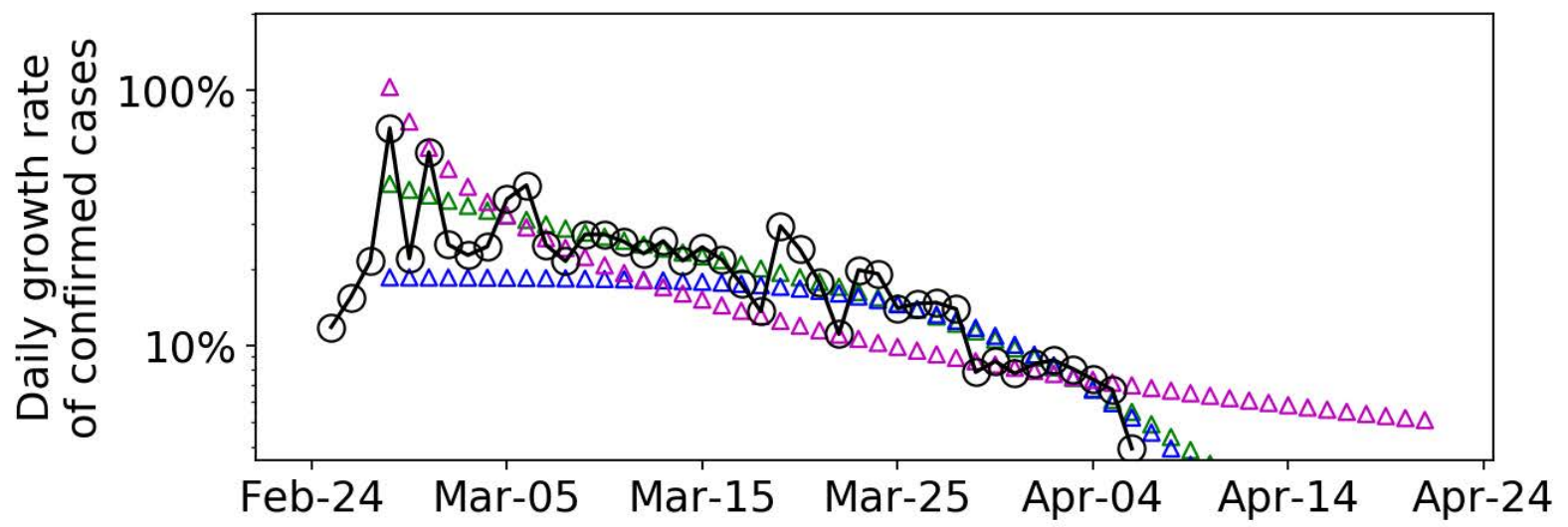
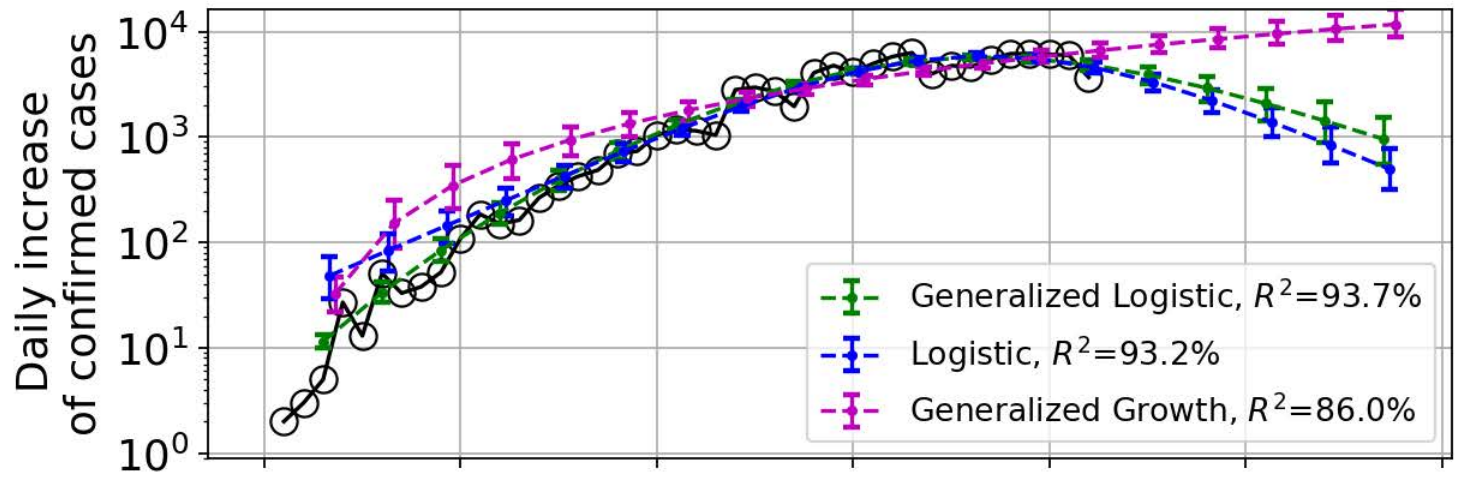
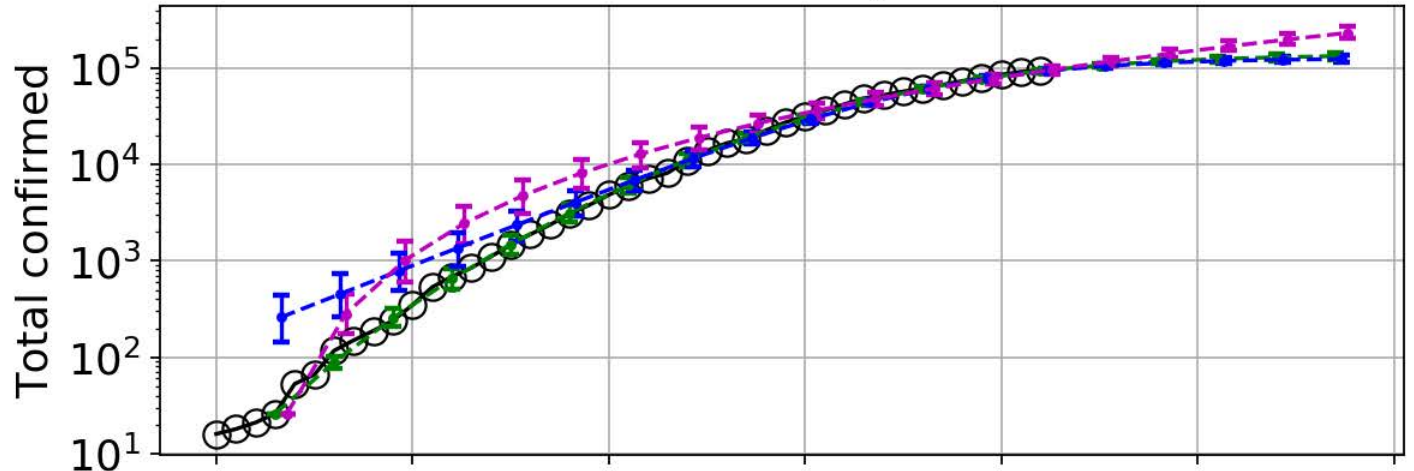
Spain



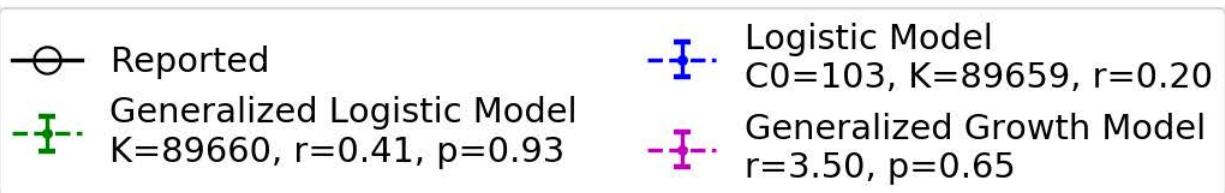
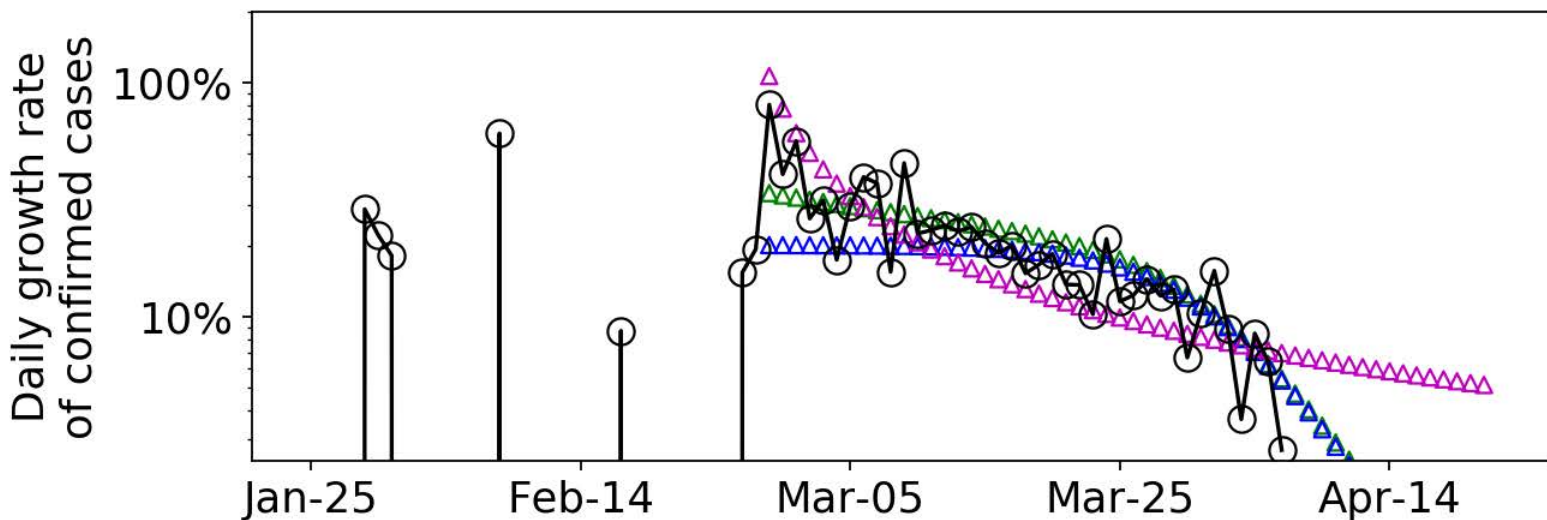
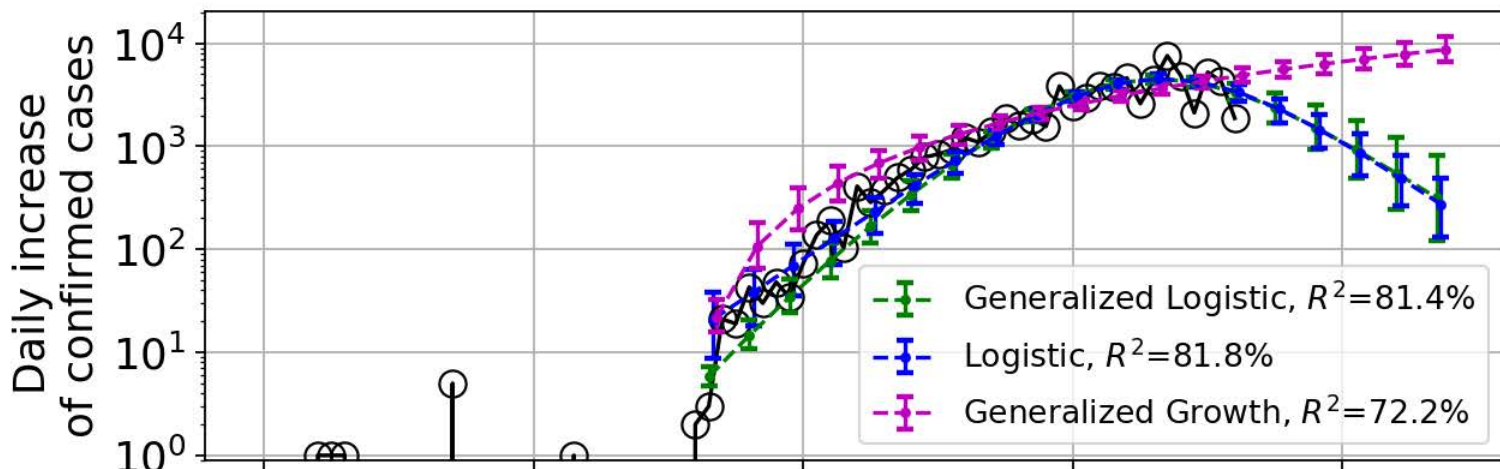
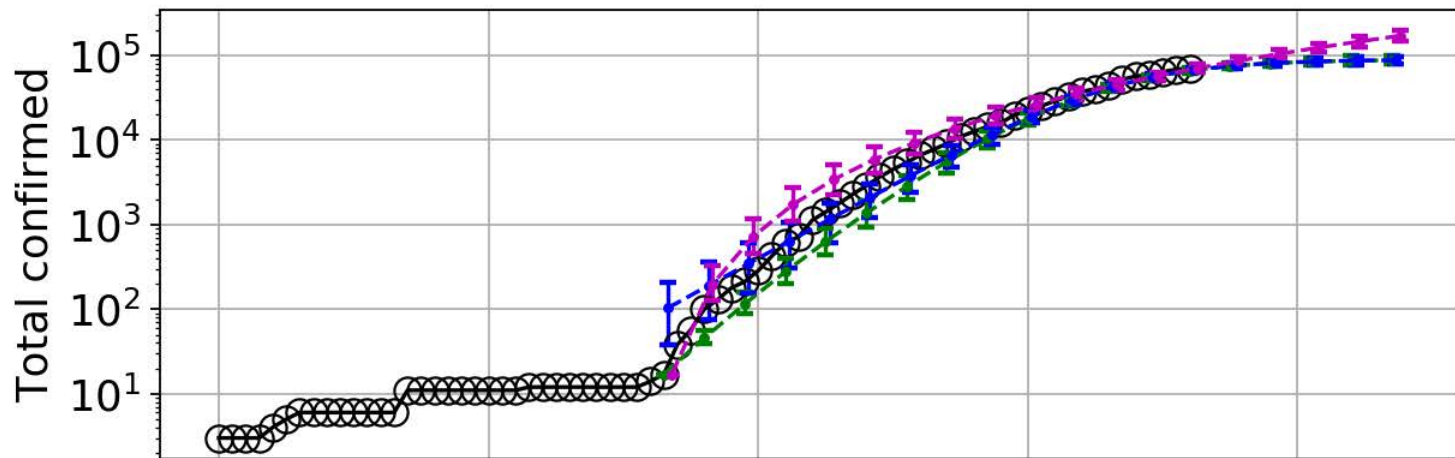
Italy



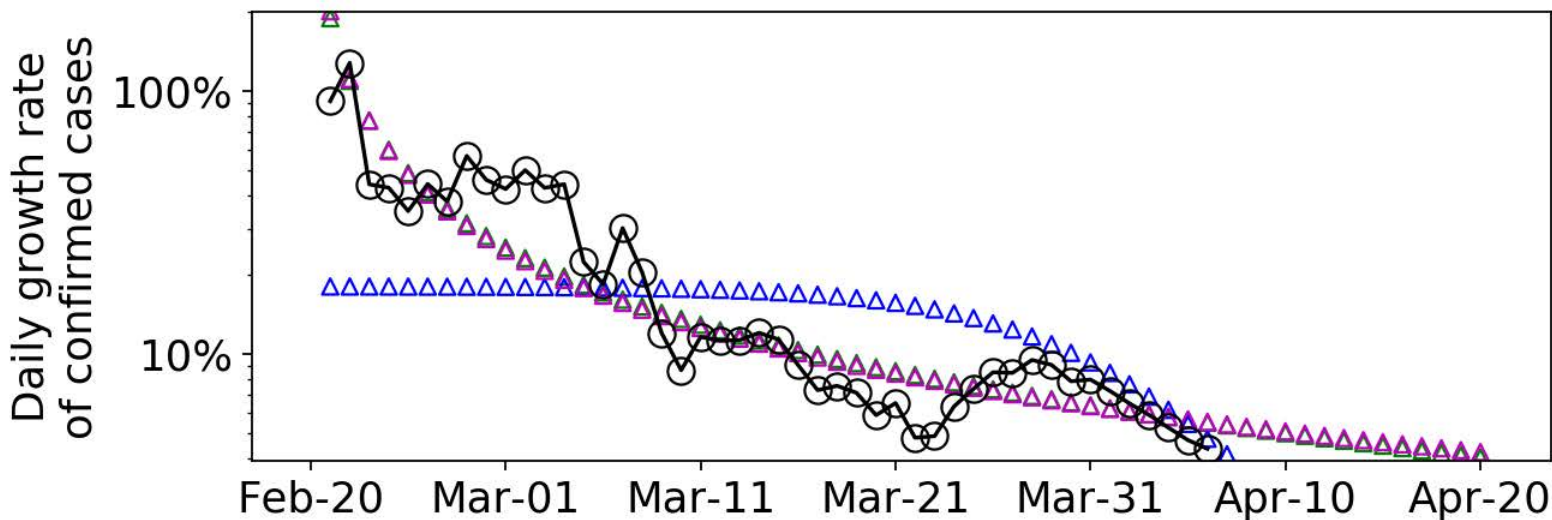
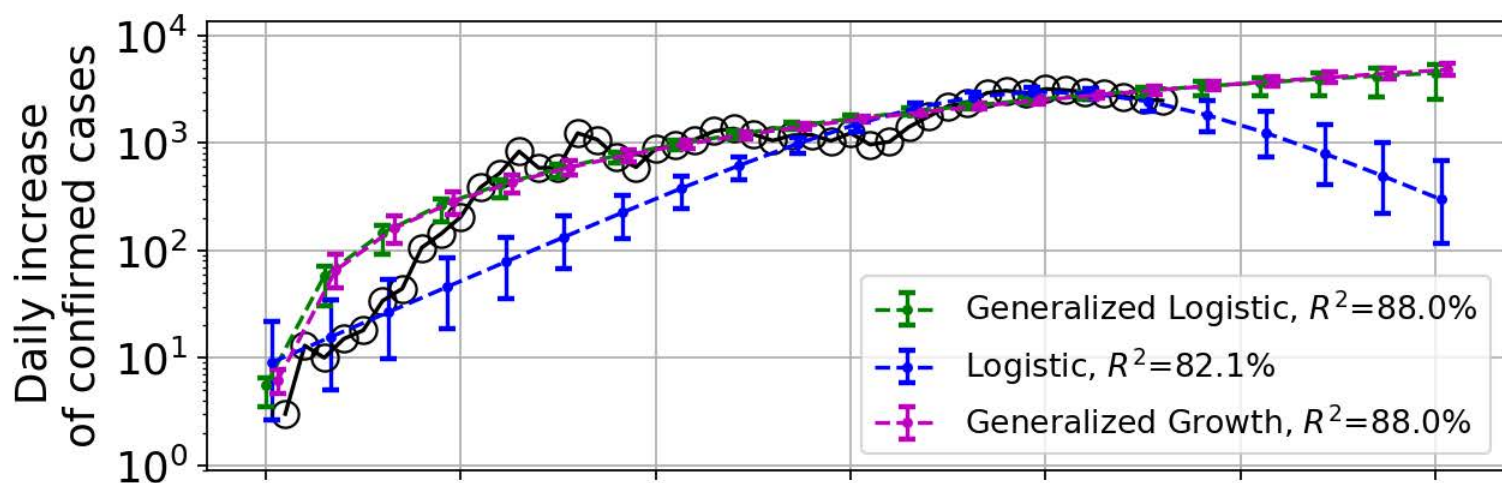
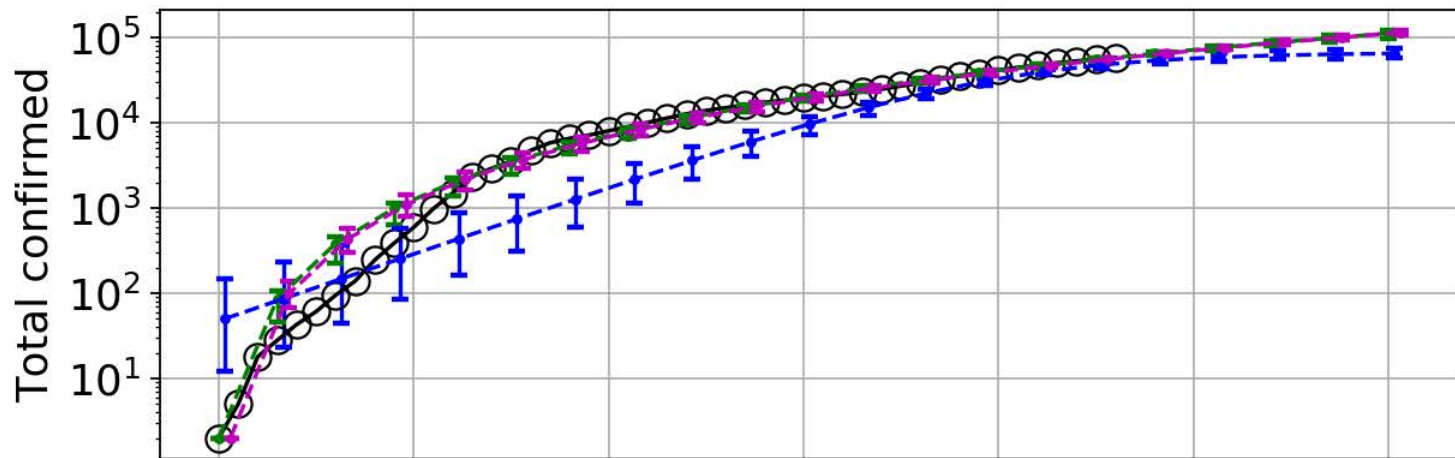
Germany



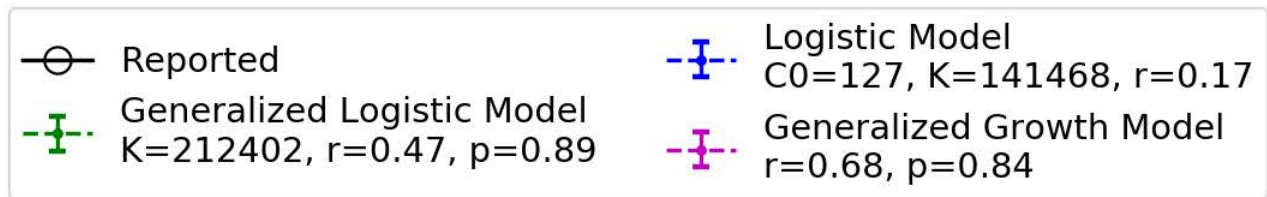
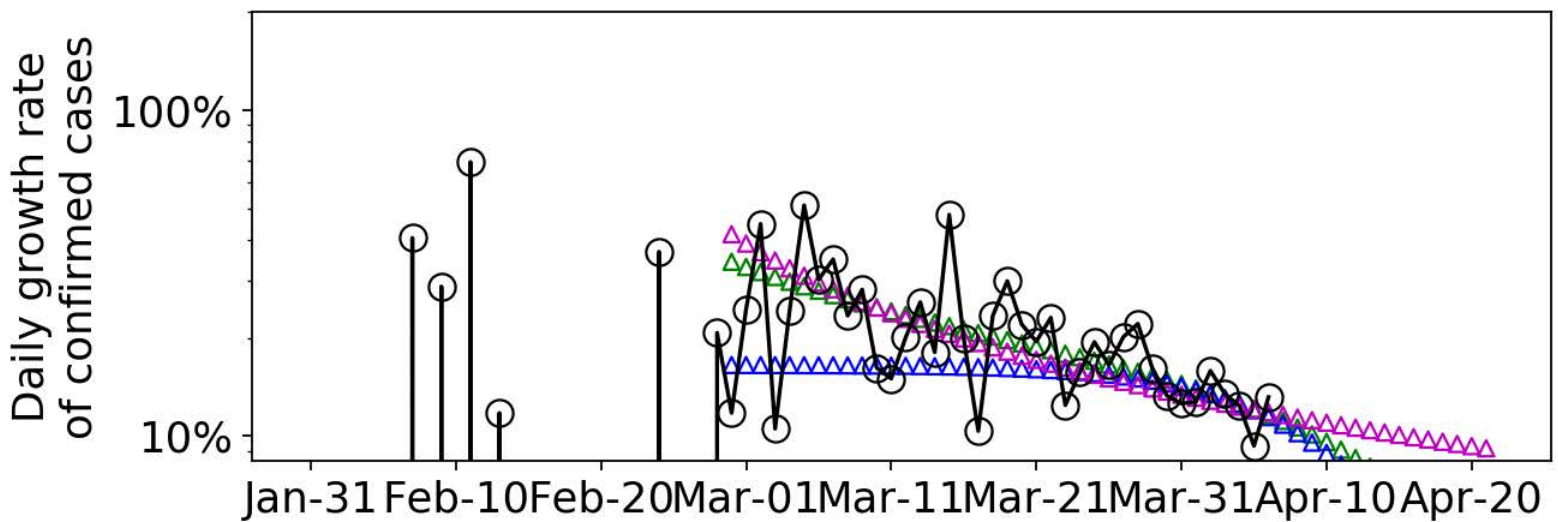
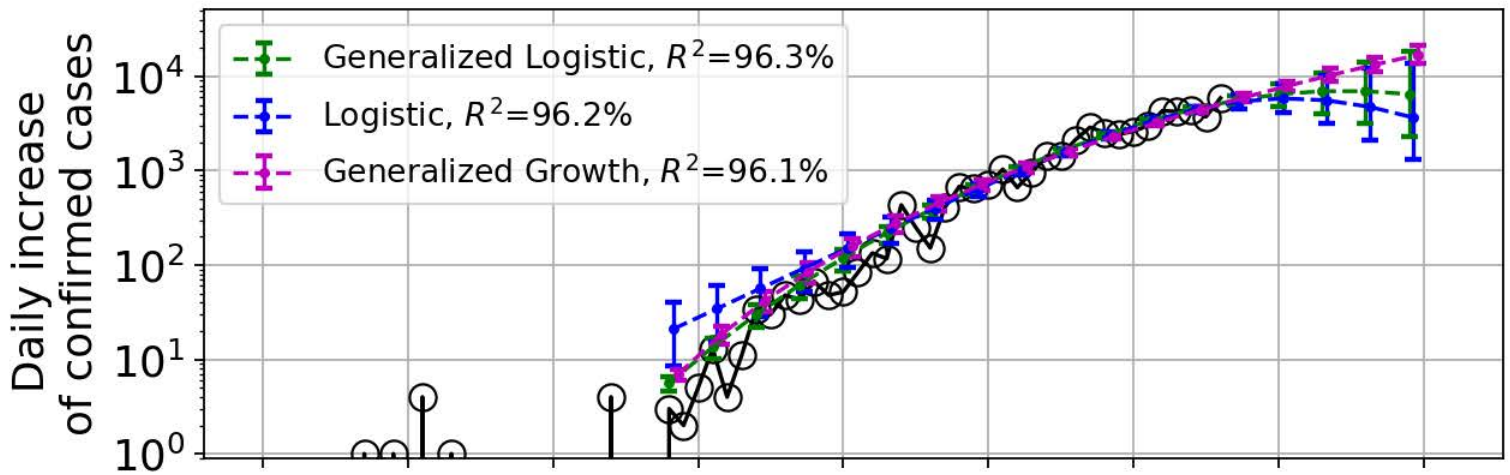
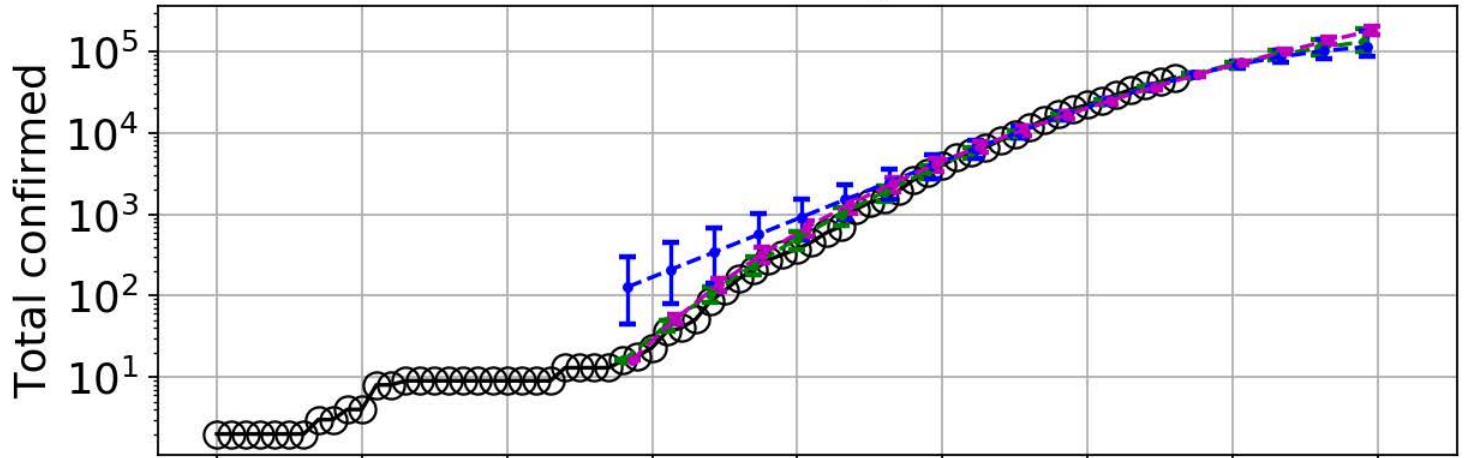
France



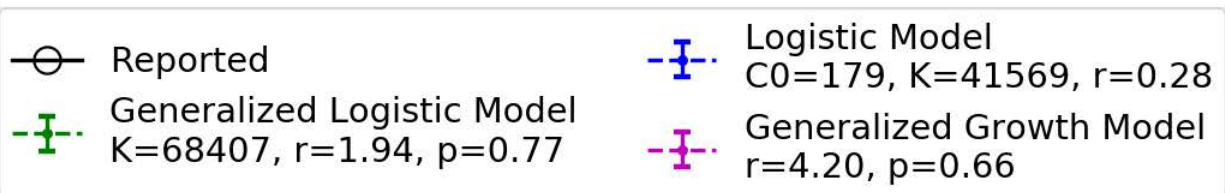
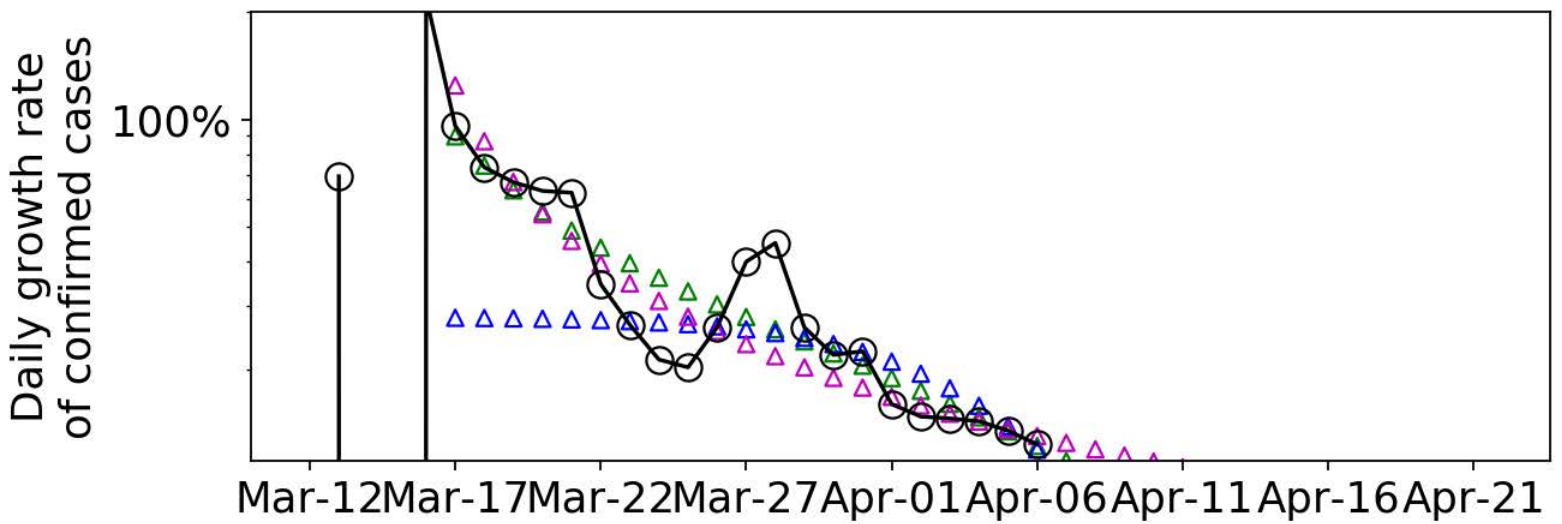
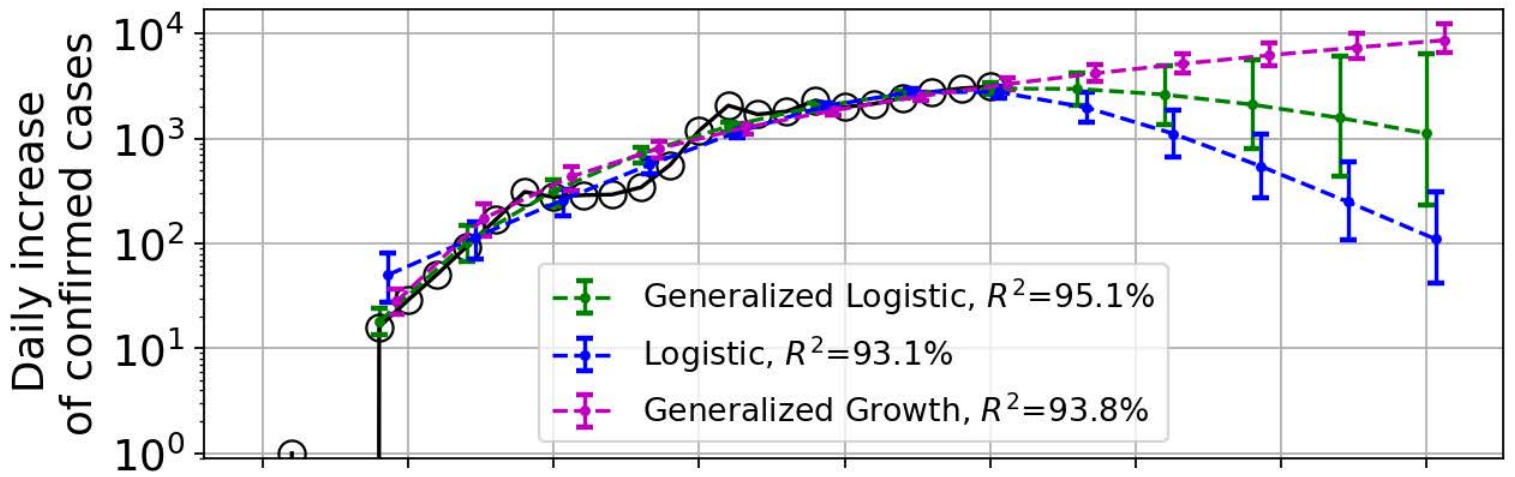
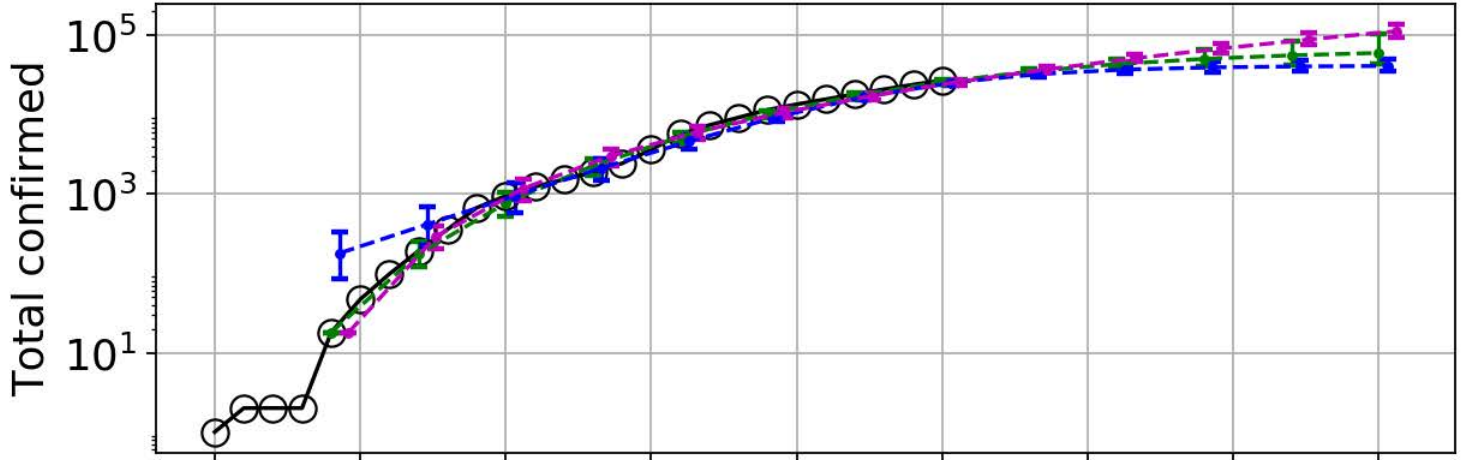
Iran



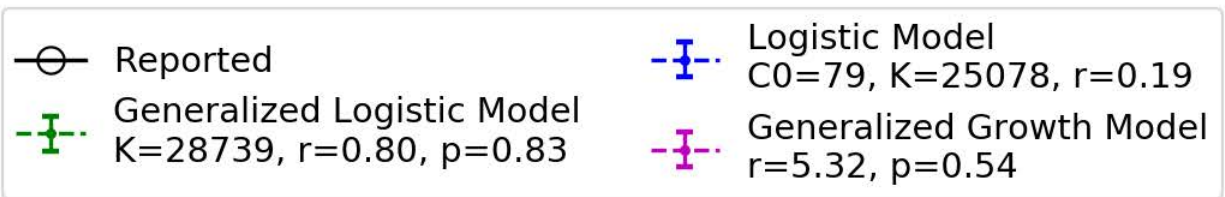
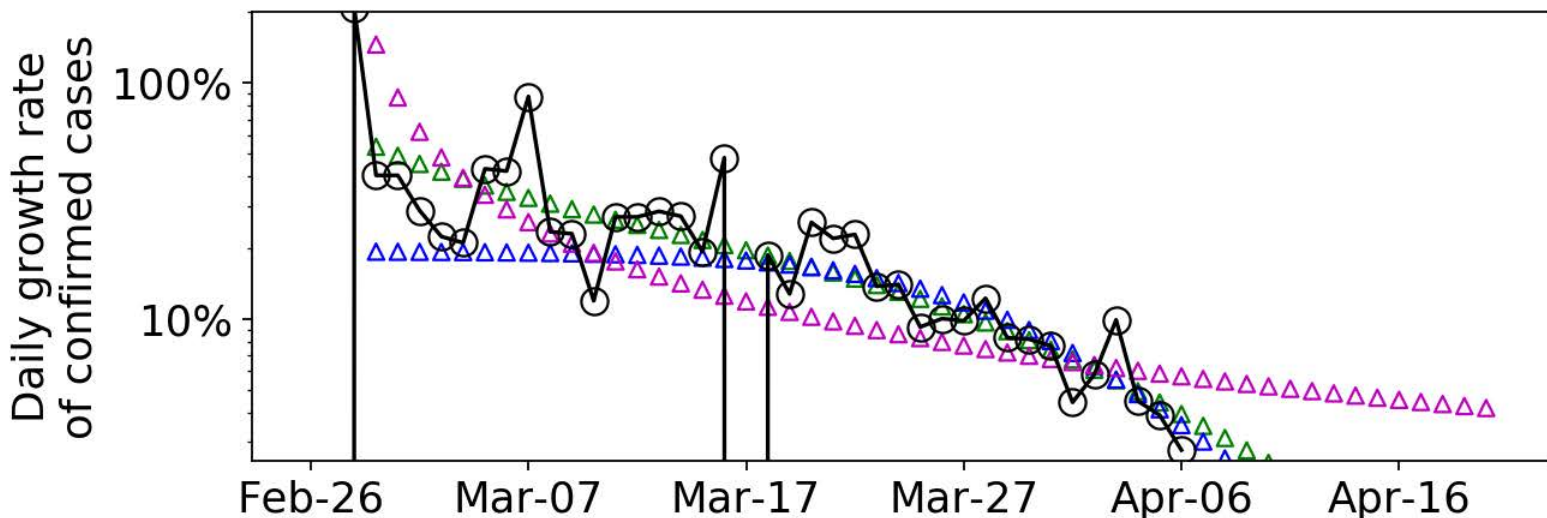
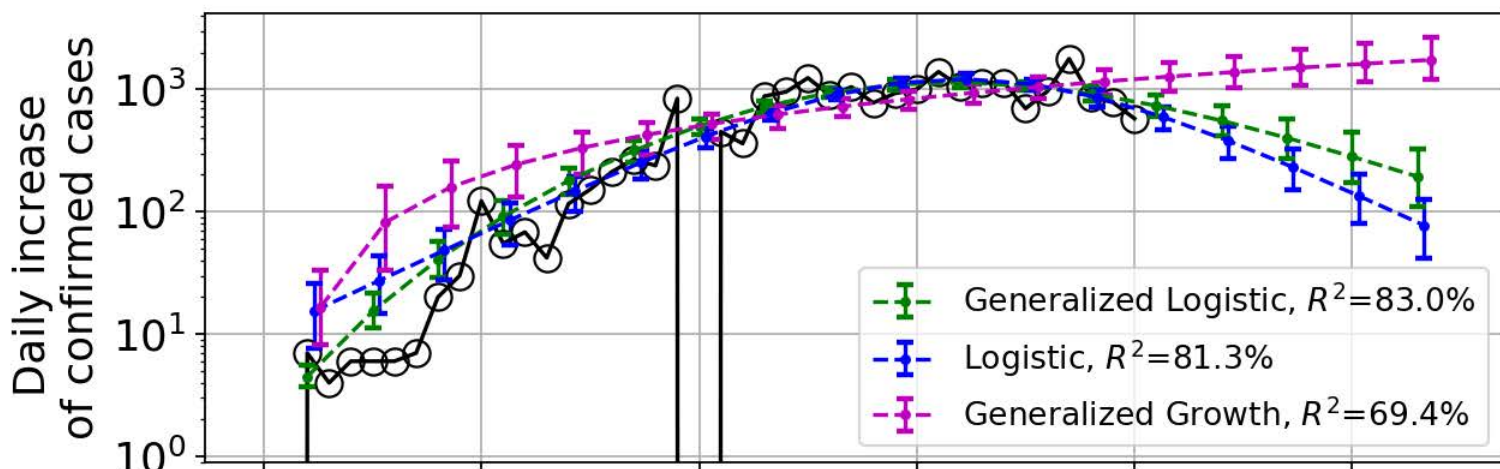
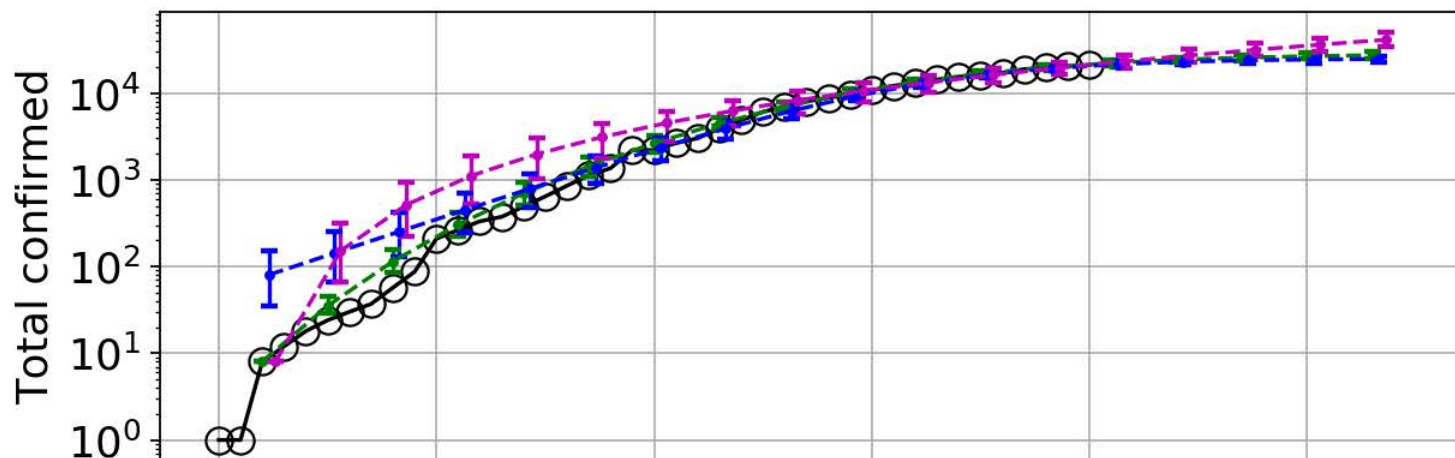
United Kingdom



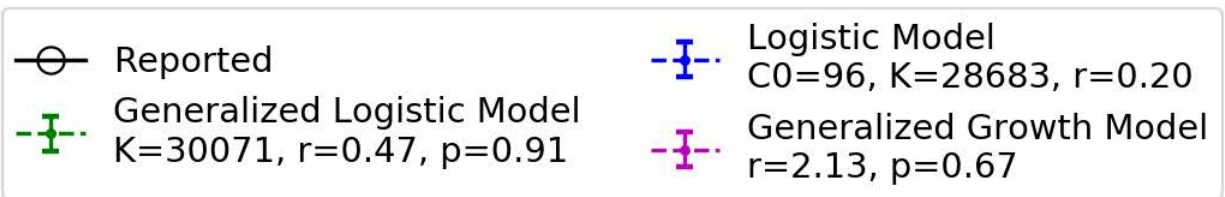
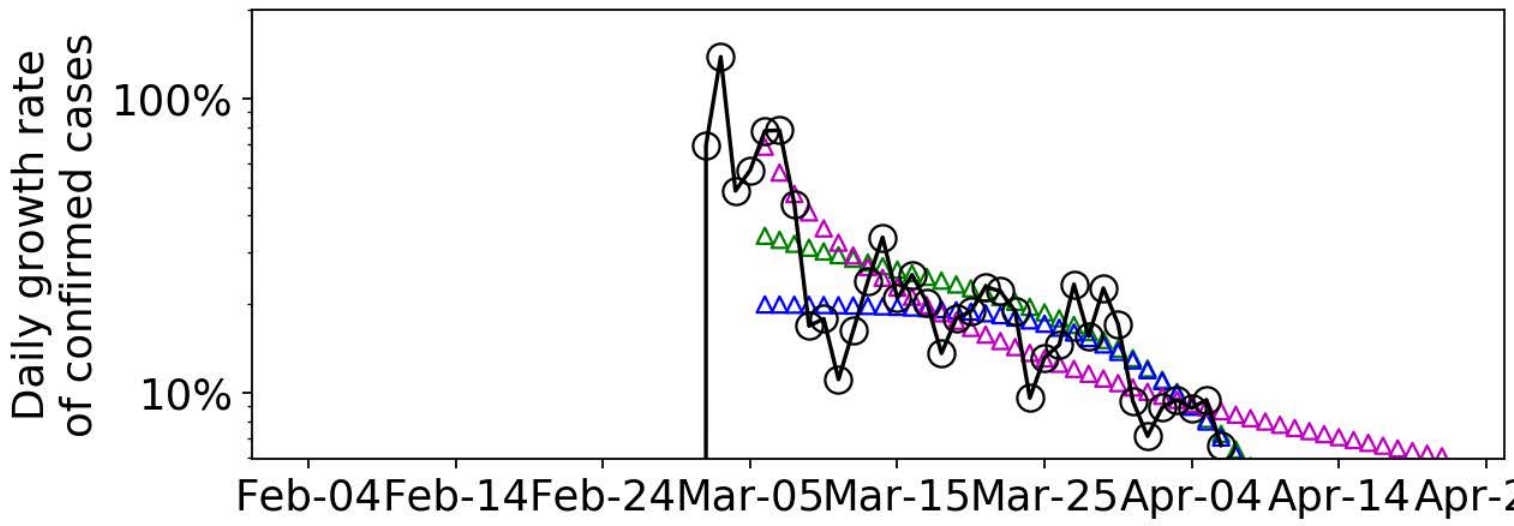
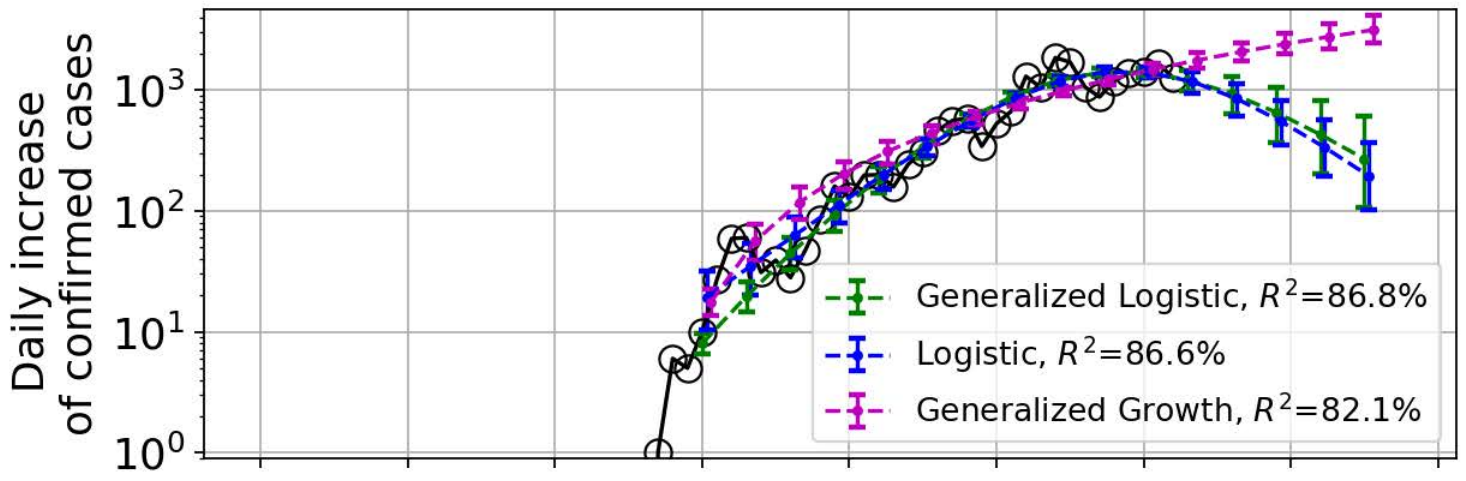
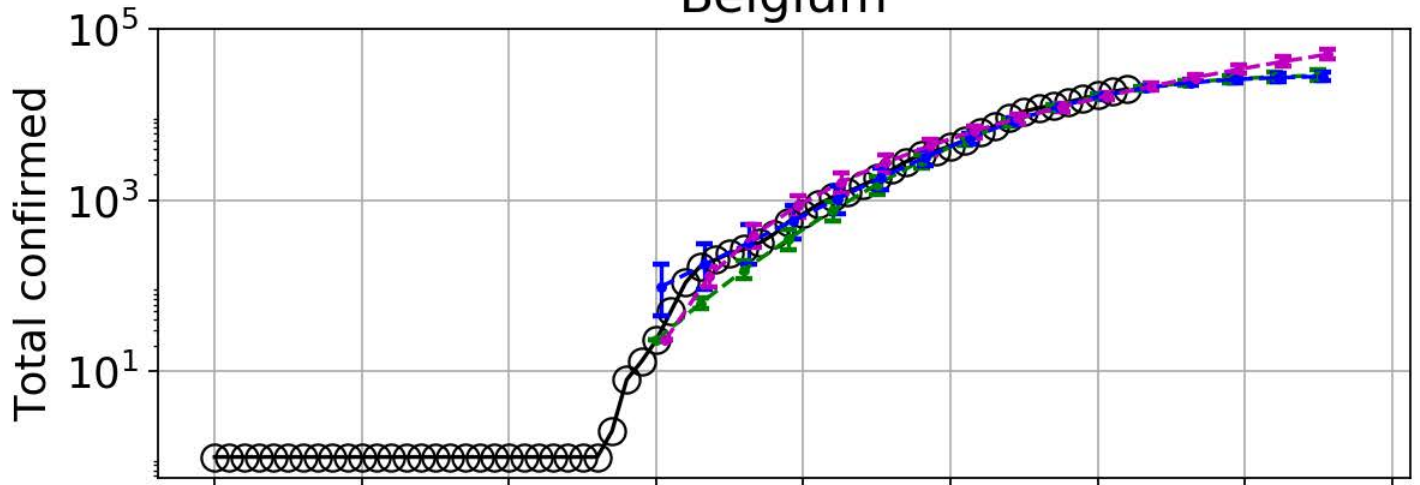
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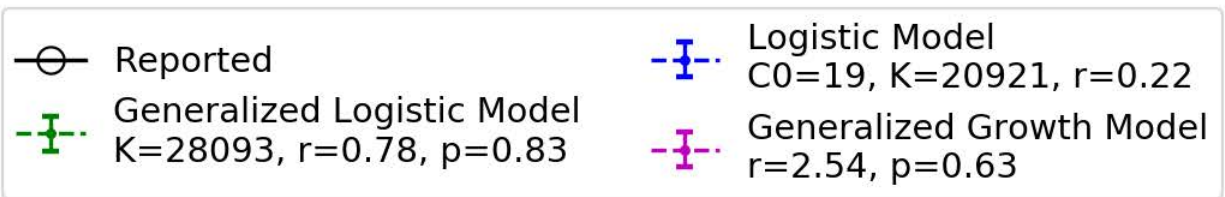
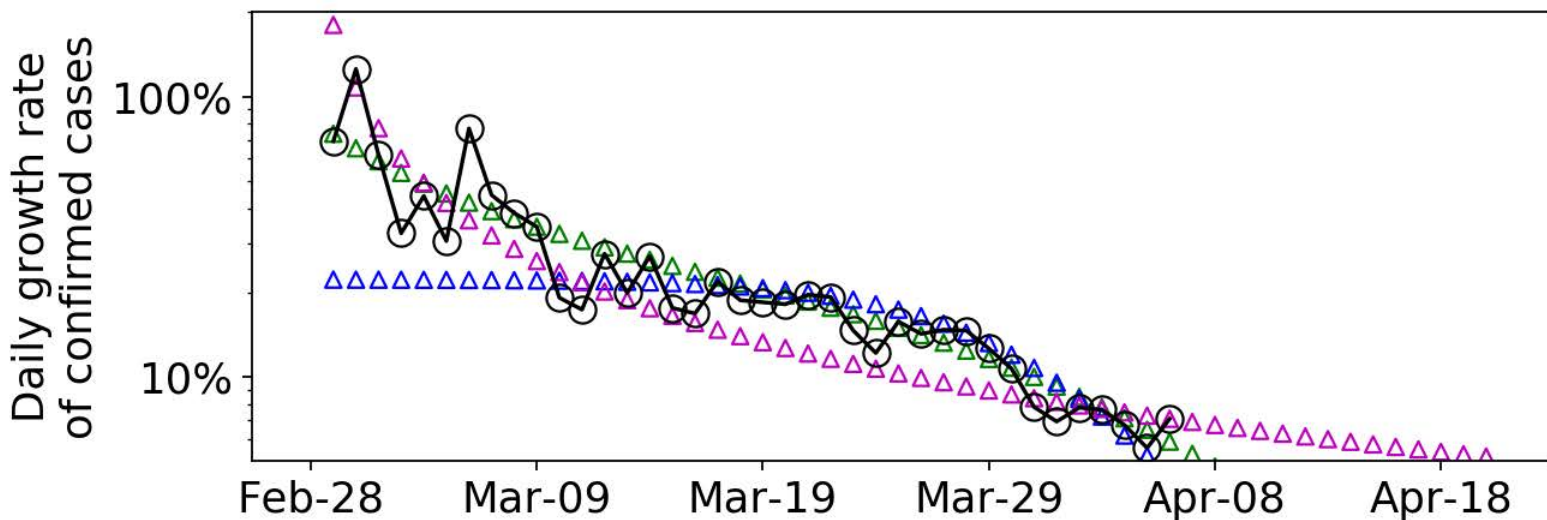
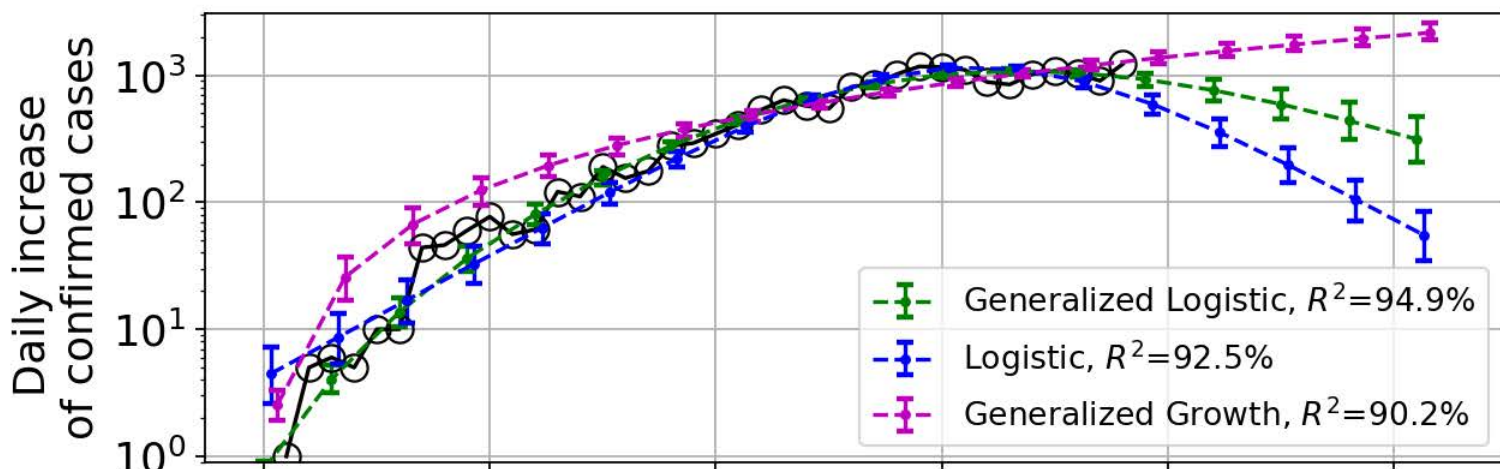
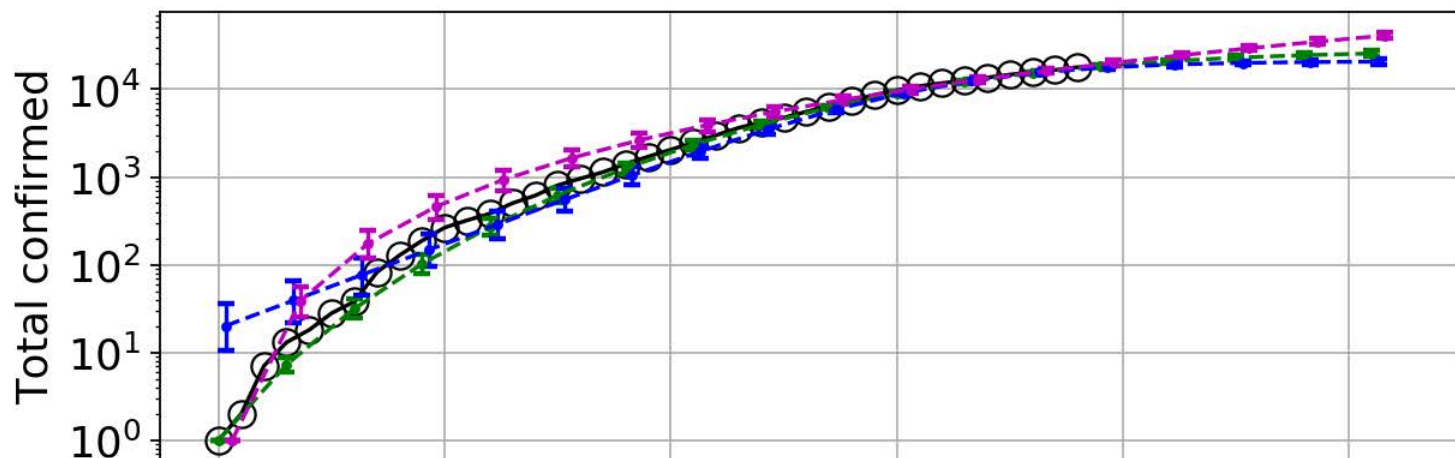
Switzerland



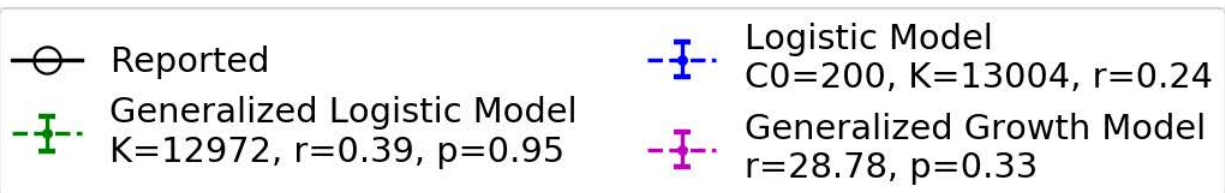
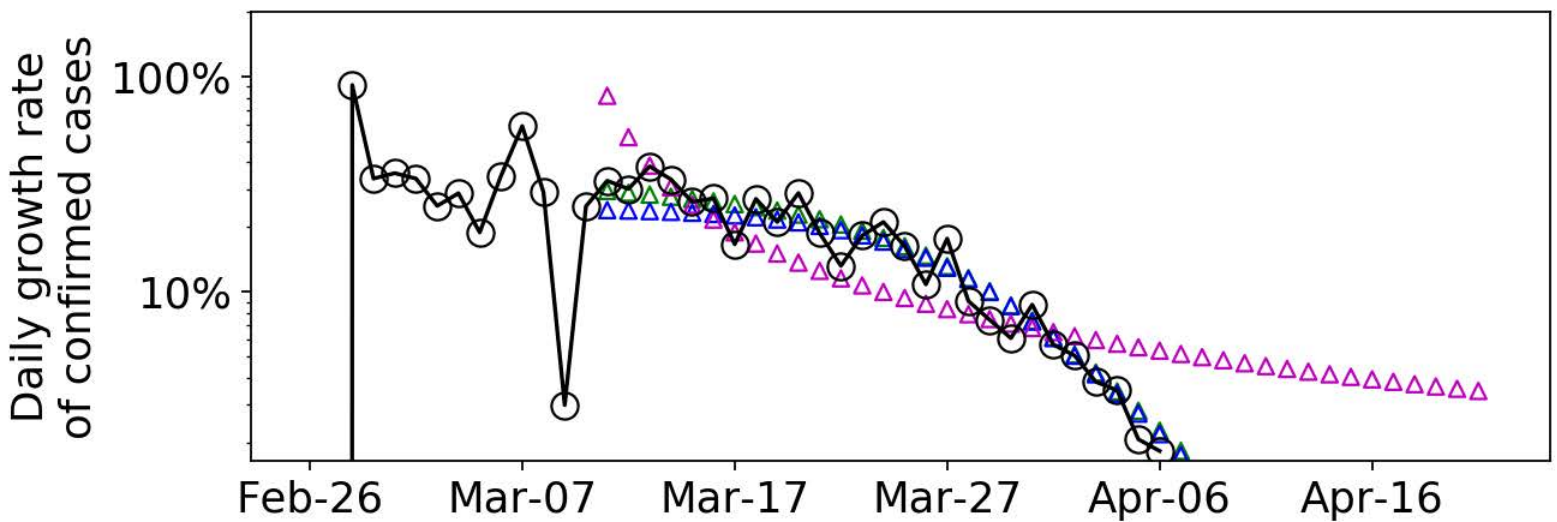
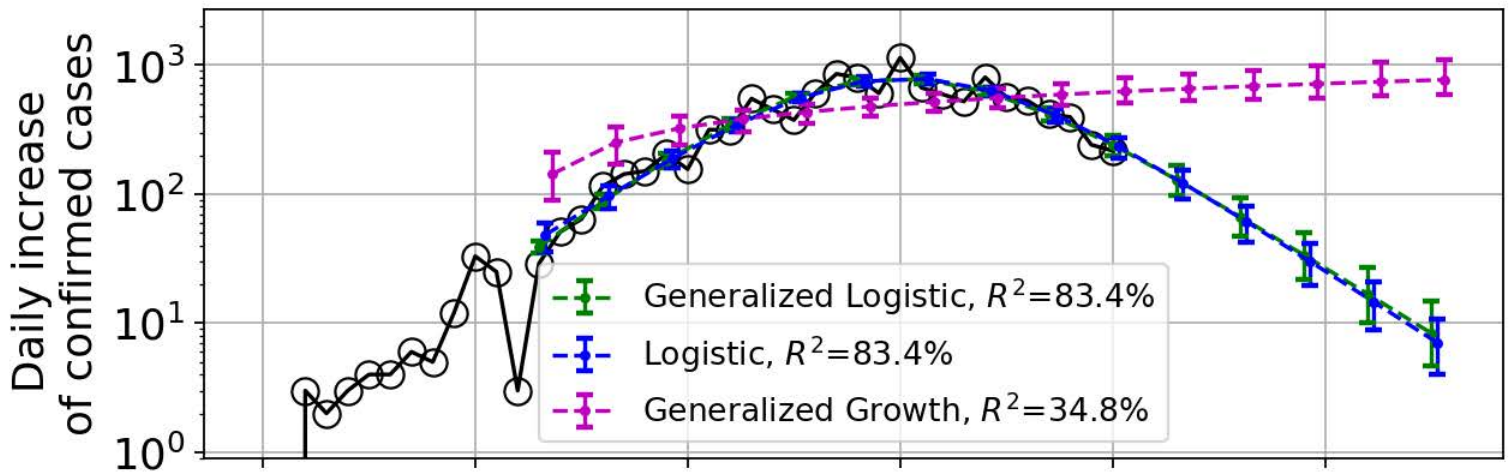
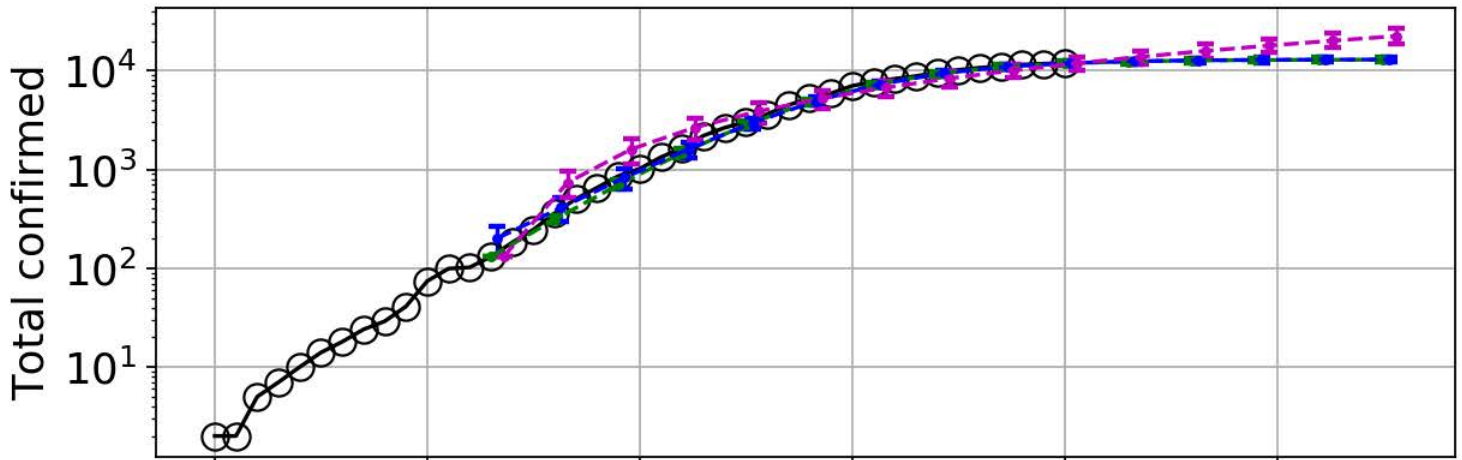
Belgium



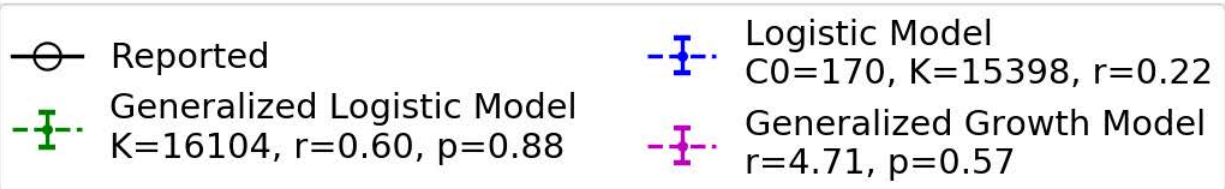
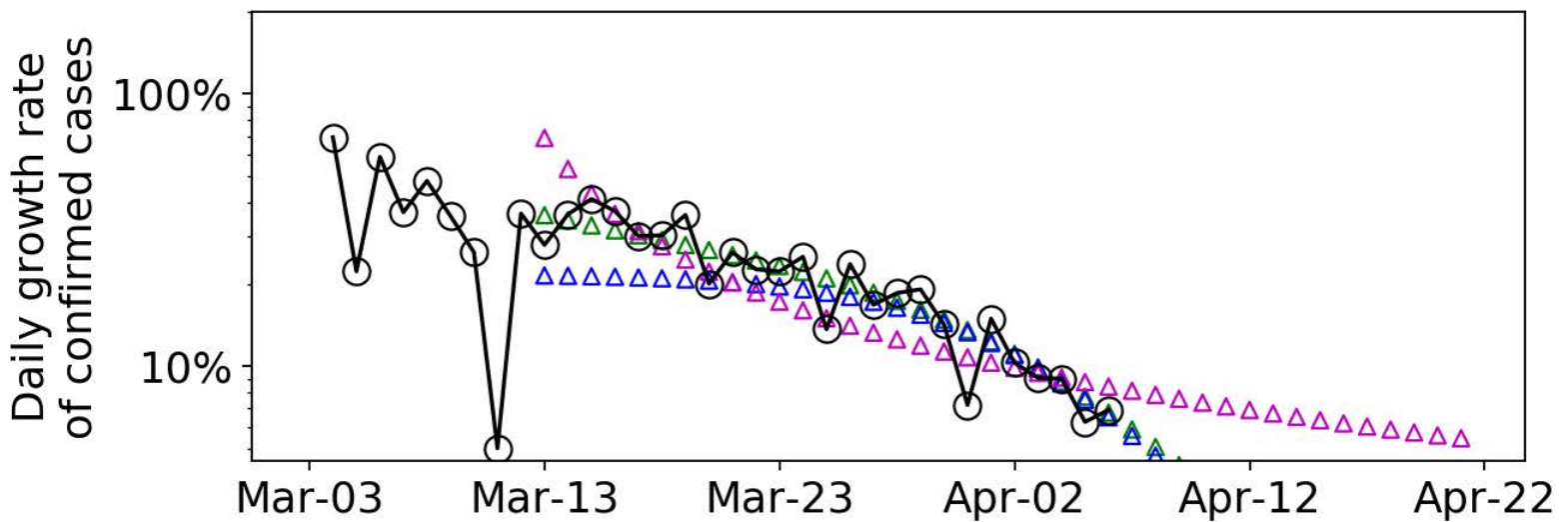
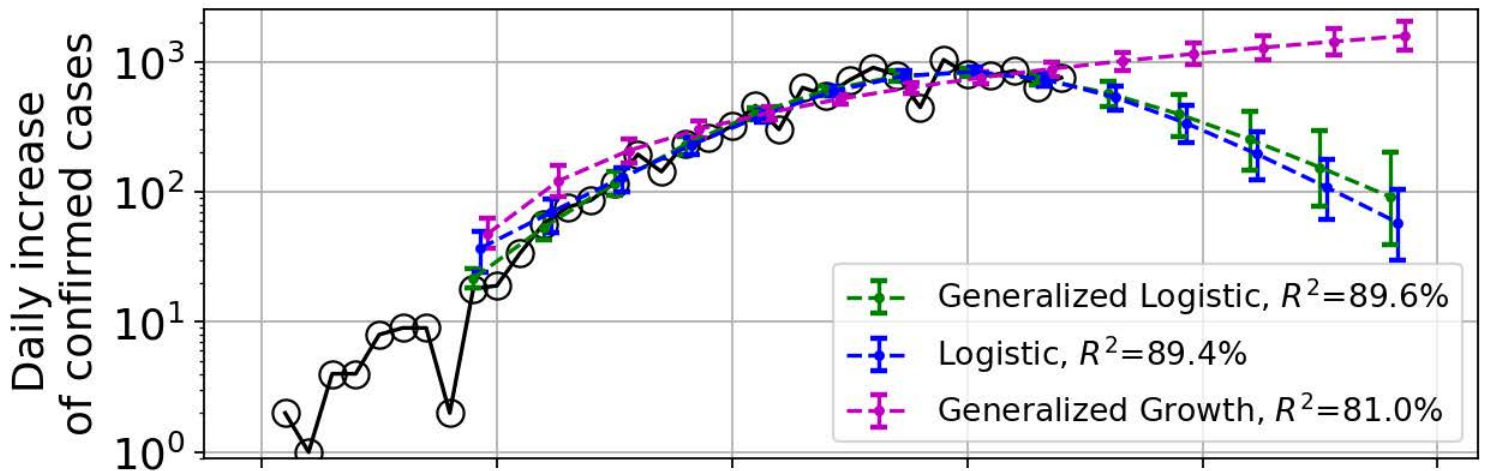
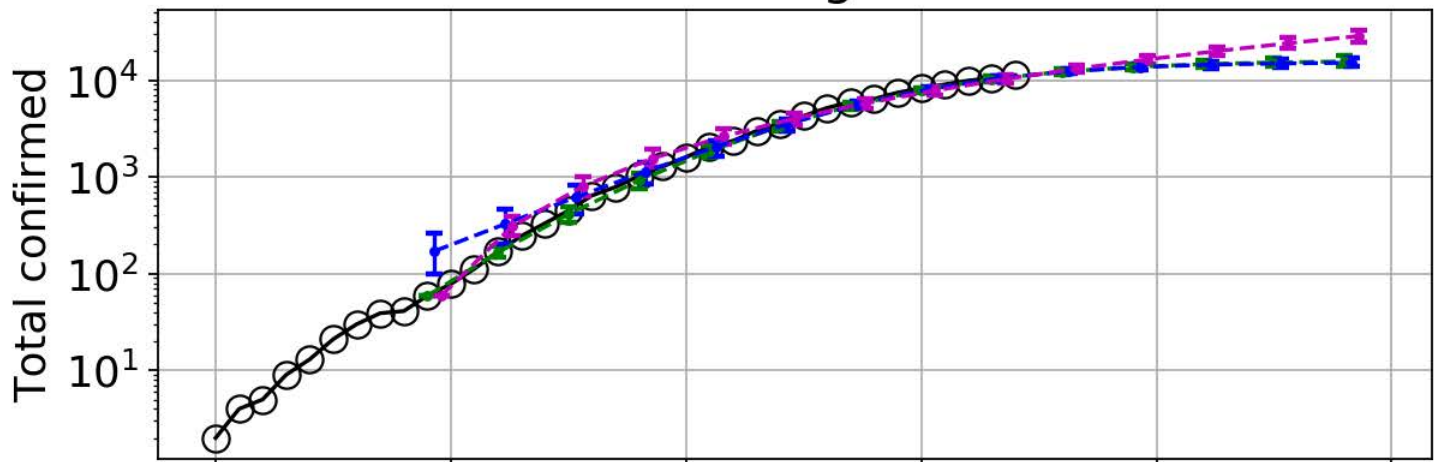
Netherlands



Austria



Portugal



Japan

