COL·LEGI D'ACTUARIS DE CATALUNYA

CONFERENCIA

MODELO EMPÍRICO PARA LA PREDICCIÓN A CORTO PLAZO DE LA PROPAGACIÓN DE LA COVID-19

Enrique Álvarez Lacalle, Grupo BIOCOMSC. UPC.

Barcelona, 28 de mayo de 2020

The use of empiric models for the short-term prediction of COVID-19. Risk assessments in epidemiological dynamics.

28th May 2020

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Tracking epidemics. A collaboration between IGTP and UPC…

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Outline

1. Context and objectives

2. An empirical model to deal with COVID19. Prediction horizon

3. Estimating real incidence of COVID19

4. Identifying risk

Context and objectives

- Research group BIOCOMSC with previous experience on modelling infectious diseases (tuberculosis, Chagas disease, malaria…) and multi/scale modelling in diseases (subcellular, cellular, organ scale).

- Follow up on COVID19 epidemic in China during January-February.

- Start **applying developed models** when COVID19 reaches **Europe**.

- Clara Prats leads the creation of a COVID19 team from the **European Commission** (DG-CONNECT, DG-SANTE) to carry out a daily analysis and prediction of the situation in EU countries (daily reports → https://biocomsc.upc.edu/en/covid-19/daily-report).

- Collaboration with **AQuAS** team that follows up epidemic in **Catalunya** → analysis and prediction at lower scale (health regions, AGAs, hospitals), including hospitalizations, critical points and ICUs. Collaboration extended to other autonomous governments

- Track evolution of the epidemics as mobility increases with the goal to detect hotspots.

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An empirical model to deal with COVID19

Why an **empirical model**?

- ✓ February 2020 → Lack of precise knowledge about the dynamics of CODIV19: incubation period, infectiousness, disease duration... → SEIR models ≈ empirical fittings with many parameters.
- ✓ Lack of herd immunity or vaccine → Dynamics of the disease is **not driven by susceptible population** (not limiting) but by control measures → SEIR models are less appropriate.

Our choice: an **empirical model** that correctly describes the cumulative cases curve and that has only **2 parameters**.

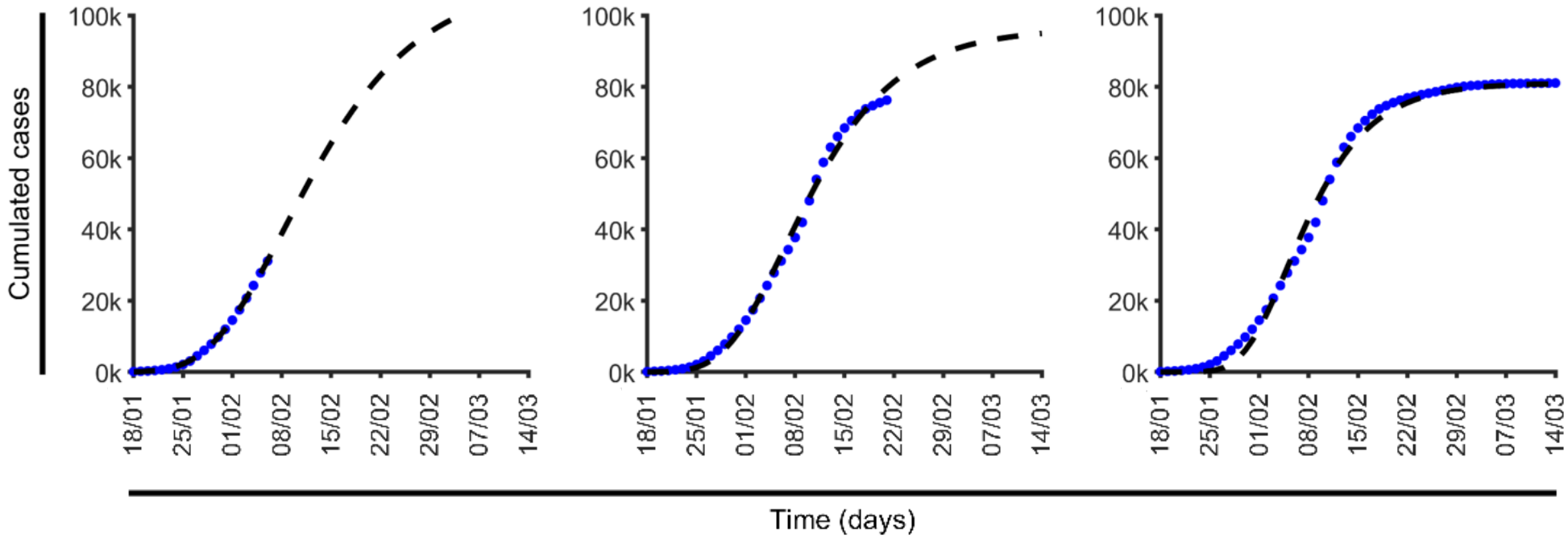
→ **Gompertz** model

Parameters of Gompertz model: *a* and *K*

Exponential growth (μ_0)

Growth slows down (a)

Maximum level (K)



$$\mu_0 = a \ln(\frac{K}{N_0})$$

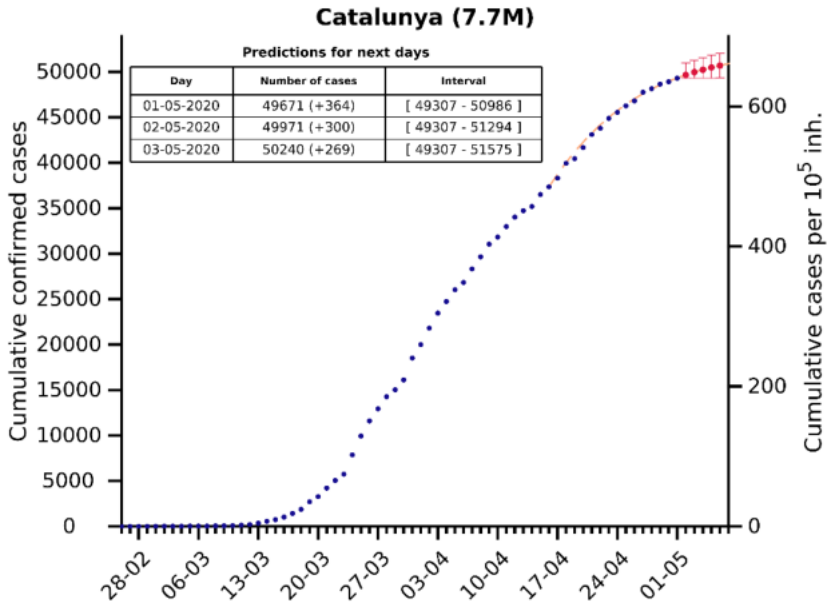
$$\frac{d\mu}{dt} = -a\mu$$

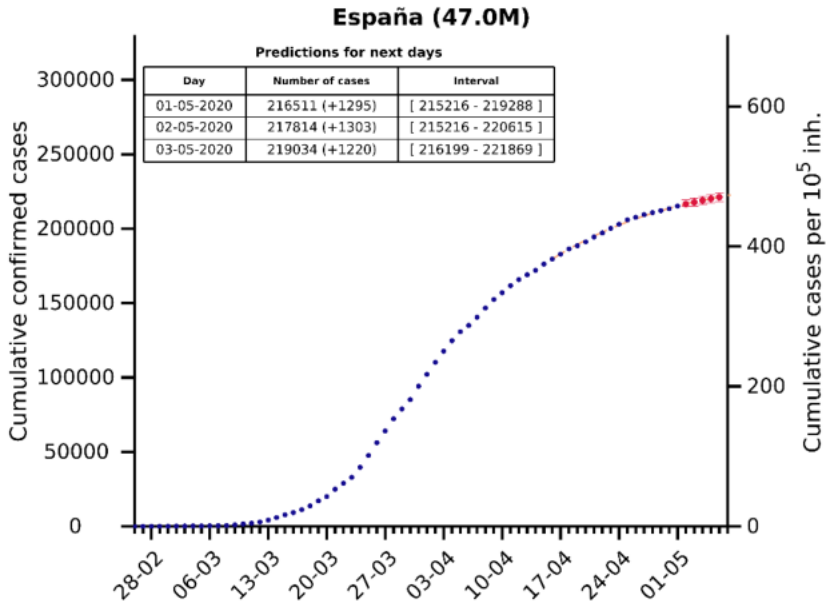
$$N(t) = Ke^{-\ln(\frac{K}{N_0})e^{-at}}$$

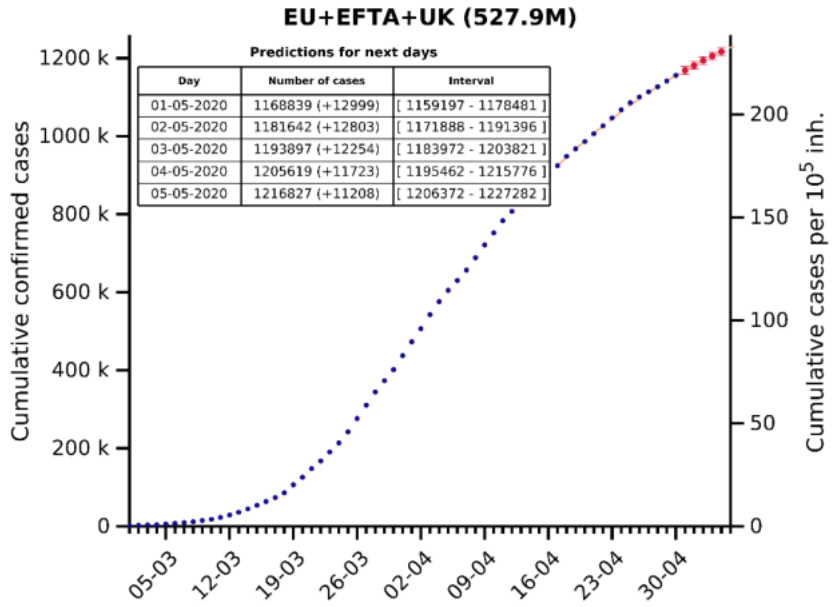
Gompertz model: predictions

Daily fitting Gompertz model to cumulative cases (countries and regions)

- Predictions at **short term** → expected cases at 1 to 5 days, depending on length of historical series







Gompertz model: predictions

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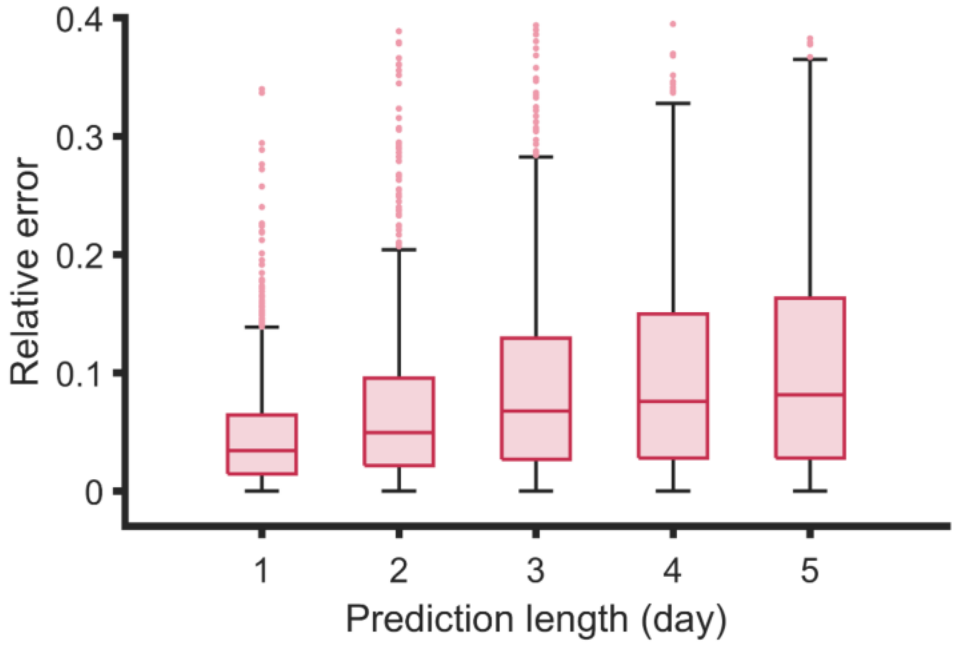
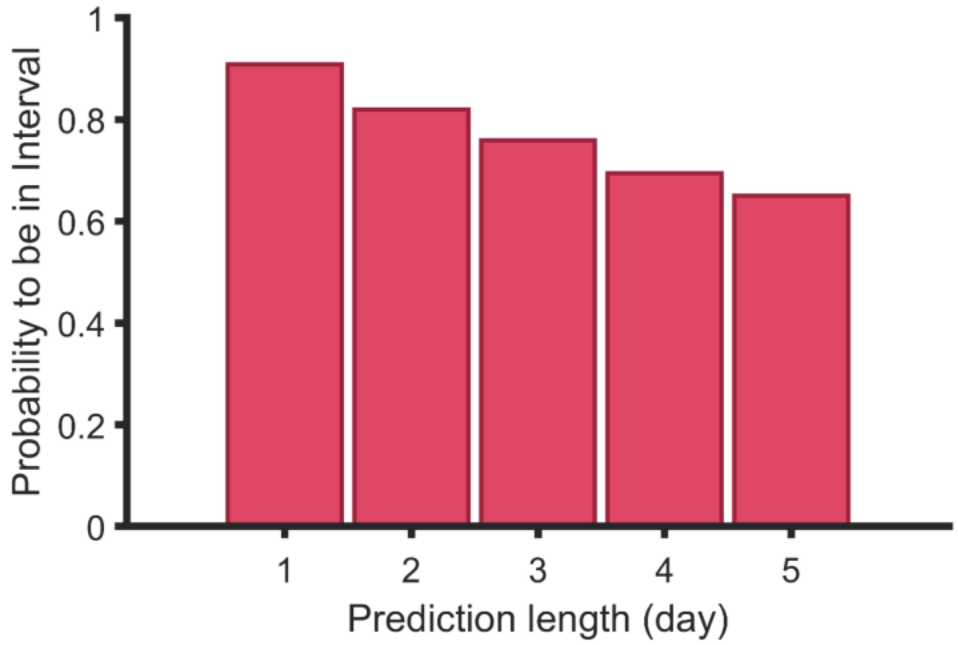
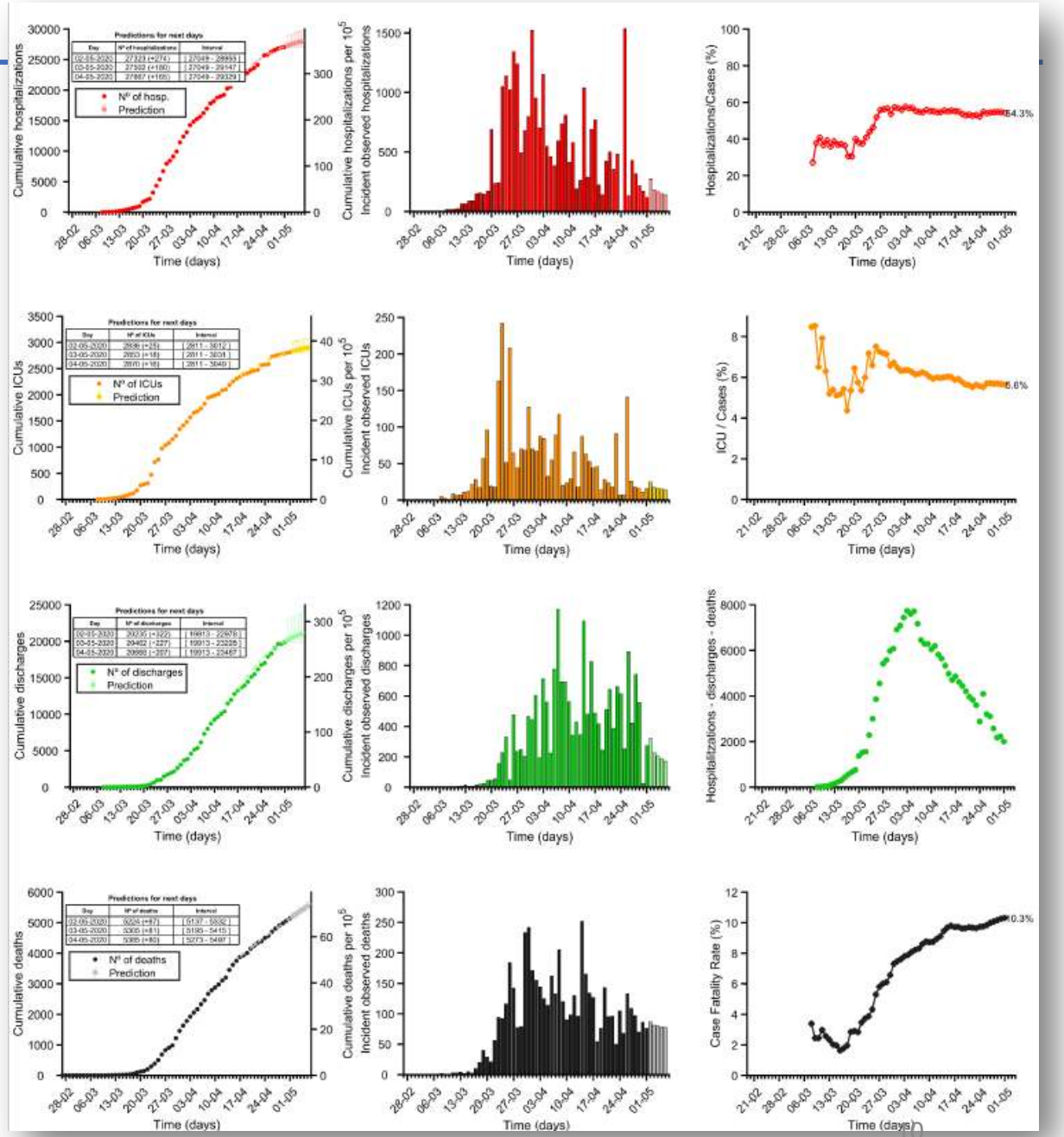




Gompertz model: Hospital coverage risk

Daily fitting Gompertz model to cumulative data

- Predictions at **short term** → also for ICUs, hospitalizations, discharges, deaths



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Why estimations of real incidence are needed to evaluate risk

- People with mild symptoms can infect others. Uncertainty about the ability of people with no symptoms (20-40%) to spread the disease

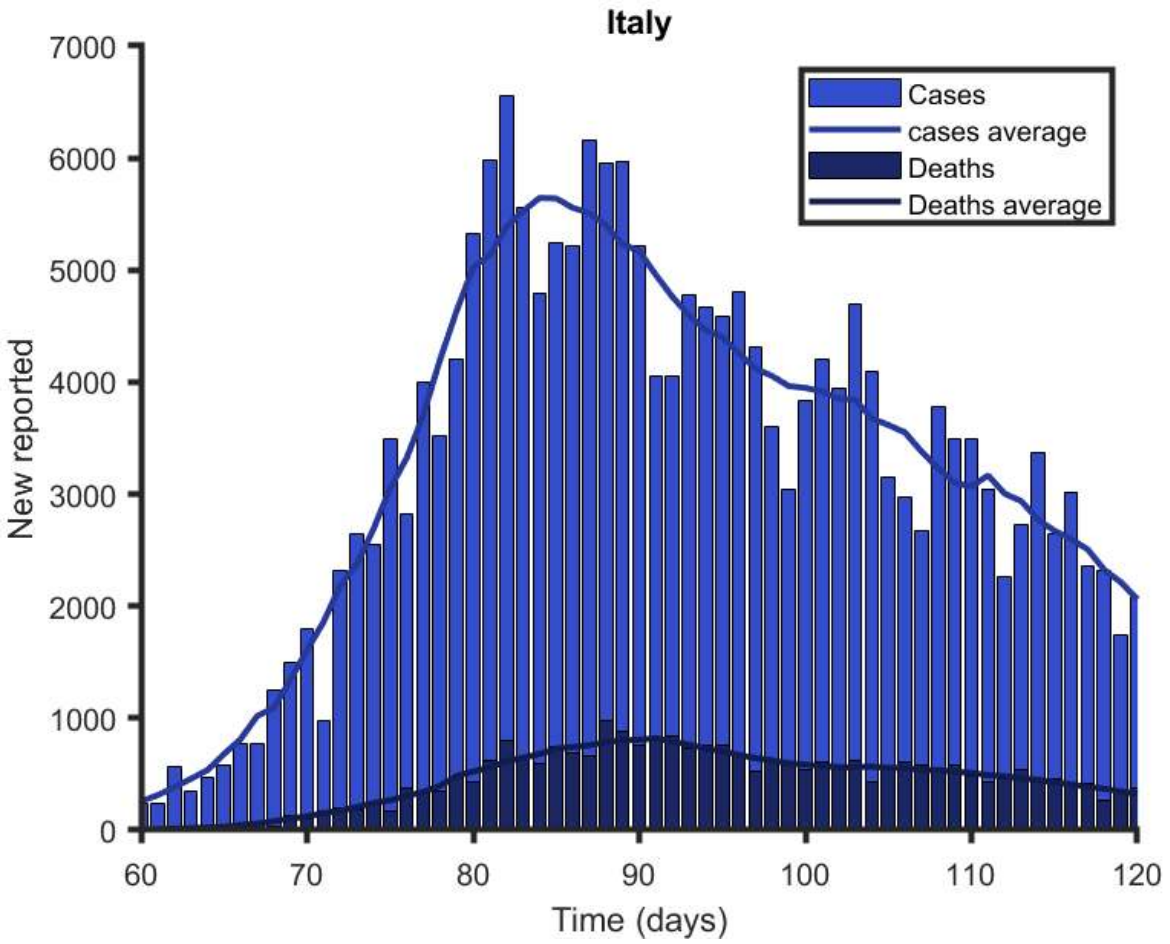
- Most countries do not have the ability to detect people with mild symptoms. Some exceptions are South Korea and Israel.

- It is important to estimate the people that are really activeCorrelation between cases and deaths → Diagnostic to Death (DtD)

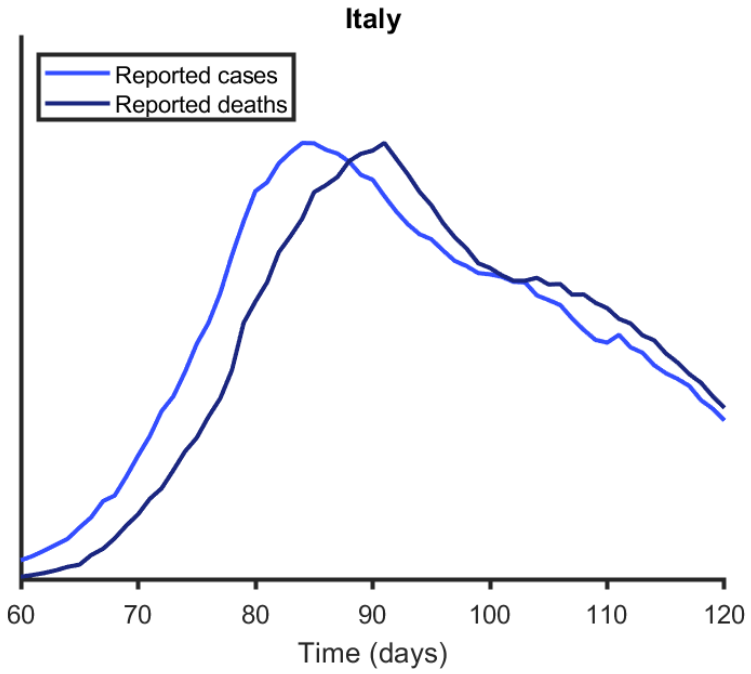
Estimating real incidence

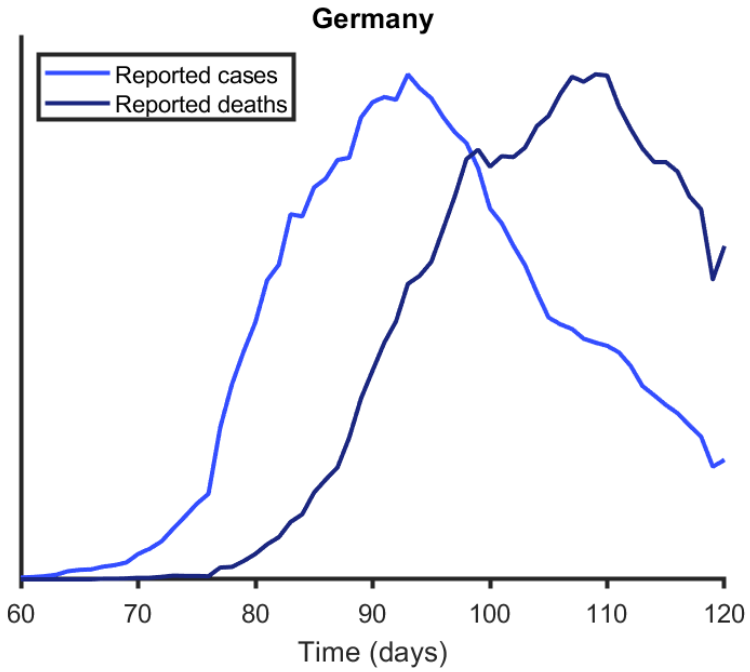
Bibliographical research and new evidence

- ✓ 1 % lethality on average
- ✓ 0.5-0.8% lethality for low penetration regions
- ✓ Up to 1.2-1.5 % on average for high penetration regions (residences, nursing homes have very high lethality)
- ✓ Time from onset to death, TtD ≤ 18 days
- ✓ Correlation between cases and deaths → Diagnostic to Death (DtD)

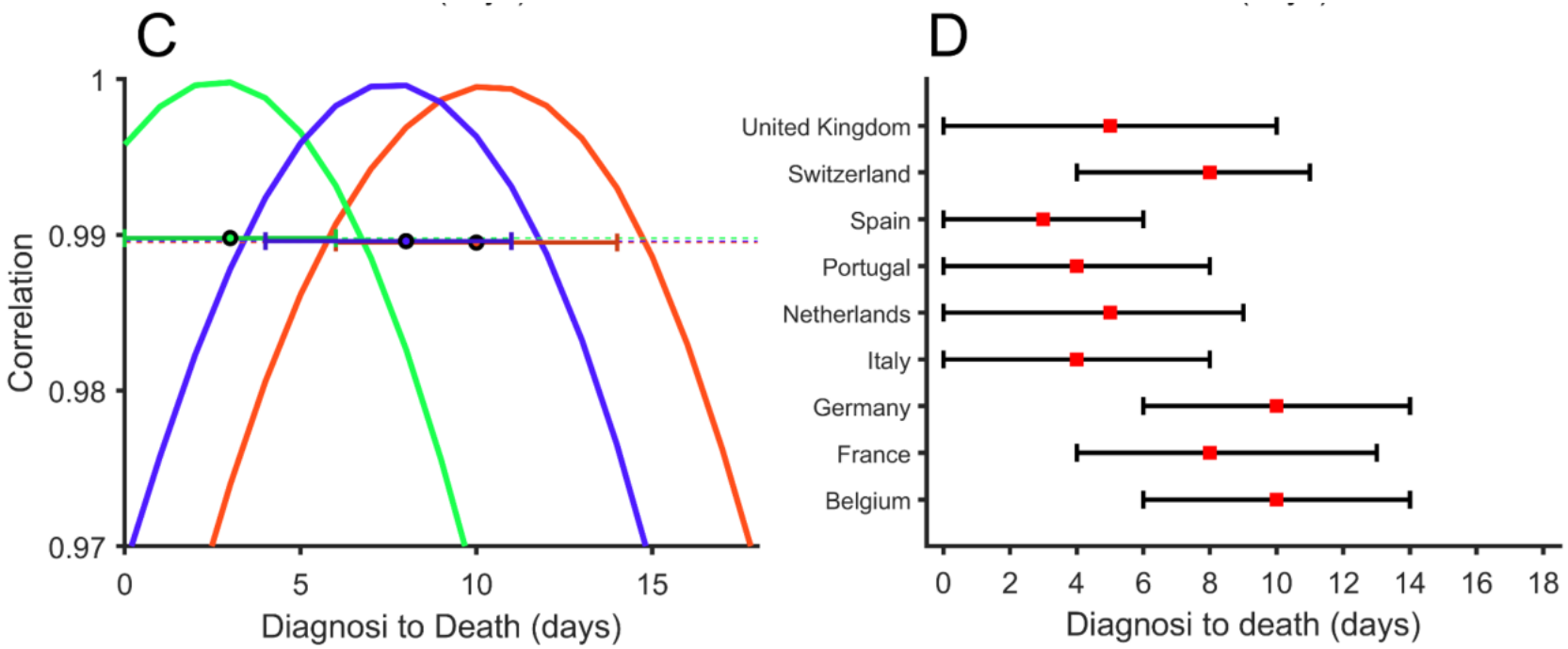


Estimating real incidence. First rescale.





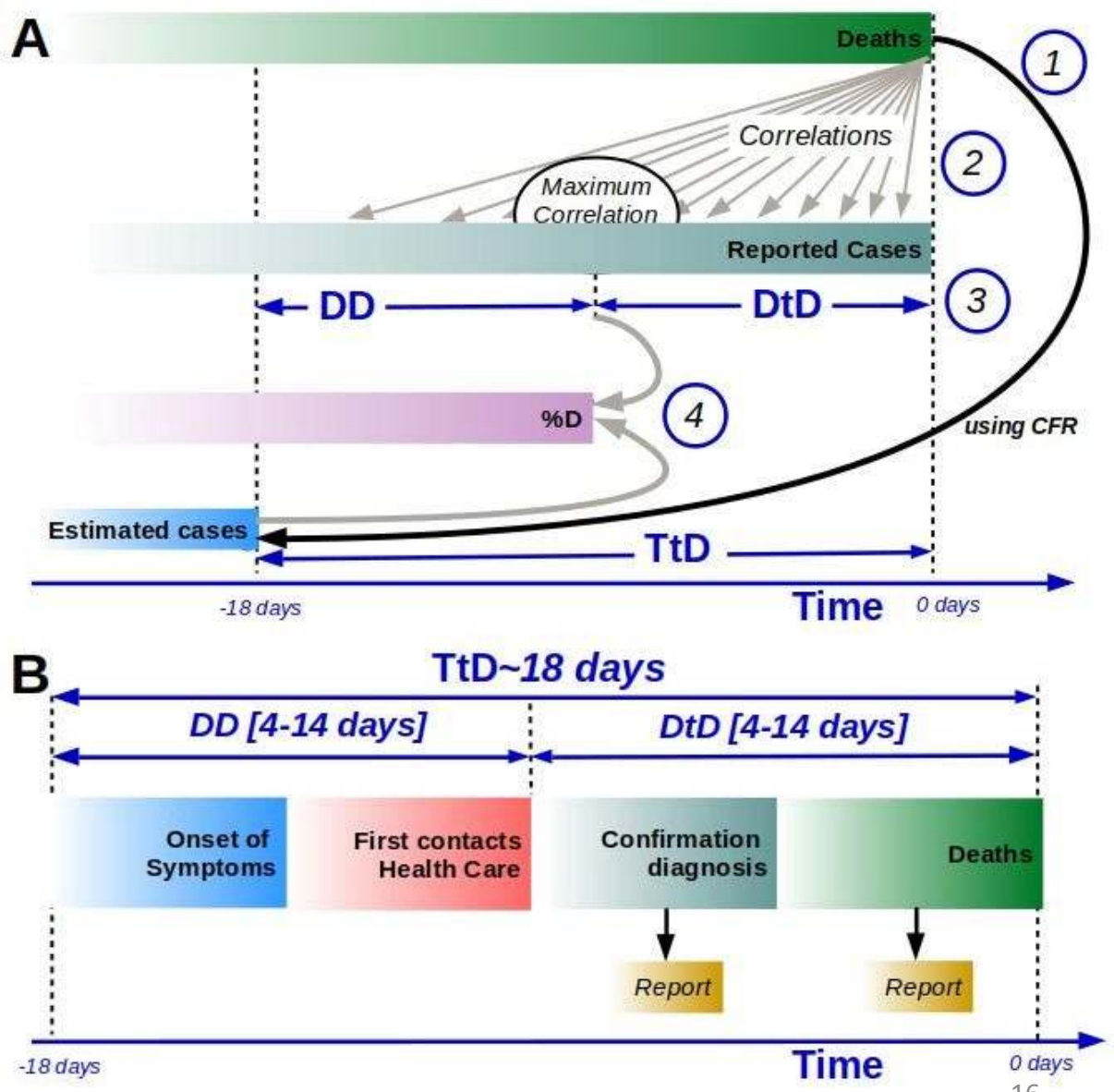
Estimating real incidence. Obtain delay



Estimating real incidence. Now consider all delays

Now take into account delays

- ✓ 1 % lethality
- ✓ Time from onset to death, TtD ≤ 18 days
- ✓ Correlation between cases and deaths → Diagnostic to Death (DtD)
- ✓ Diagnosis Delay DD = TtD – DtD
- ✓ DD includes delay in data recording



Estimating real incidence

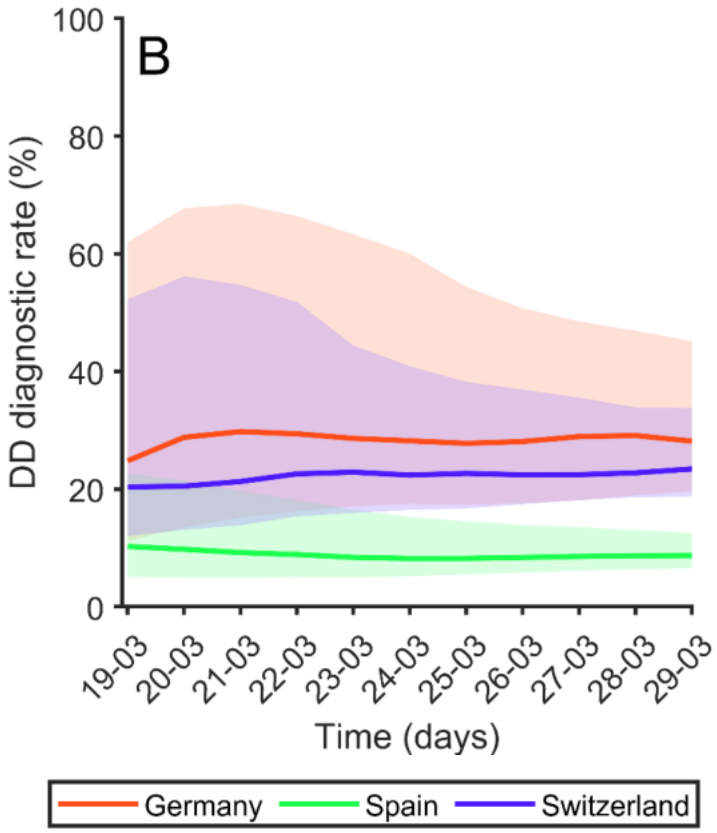
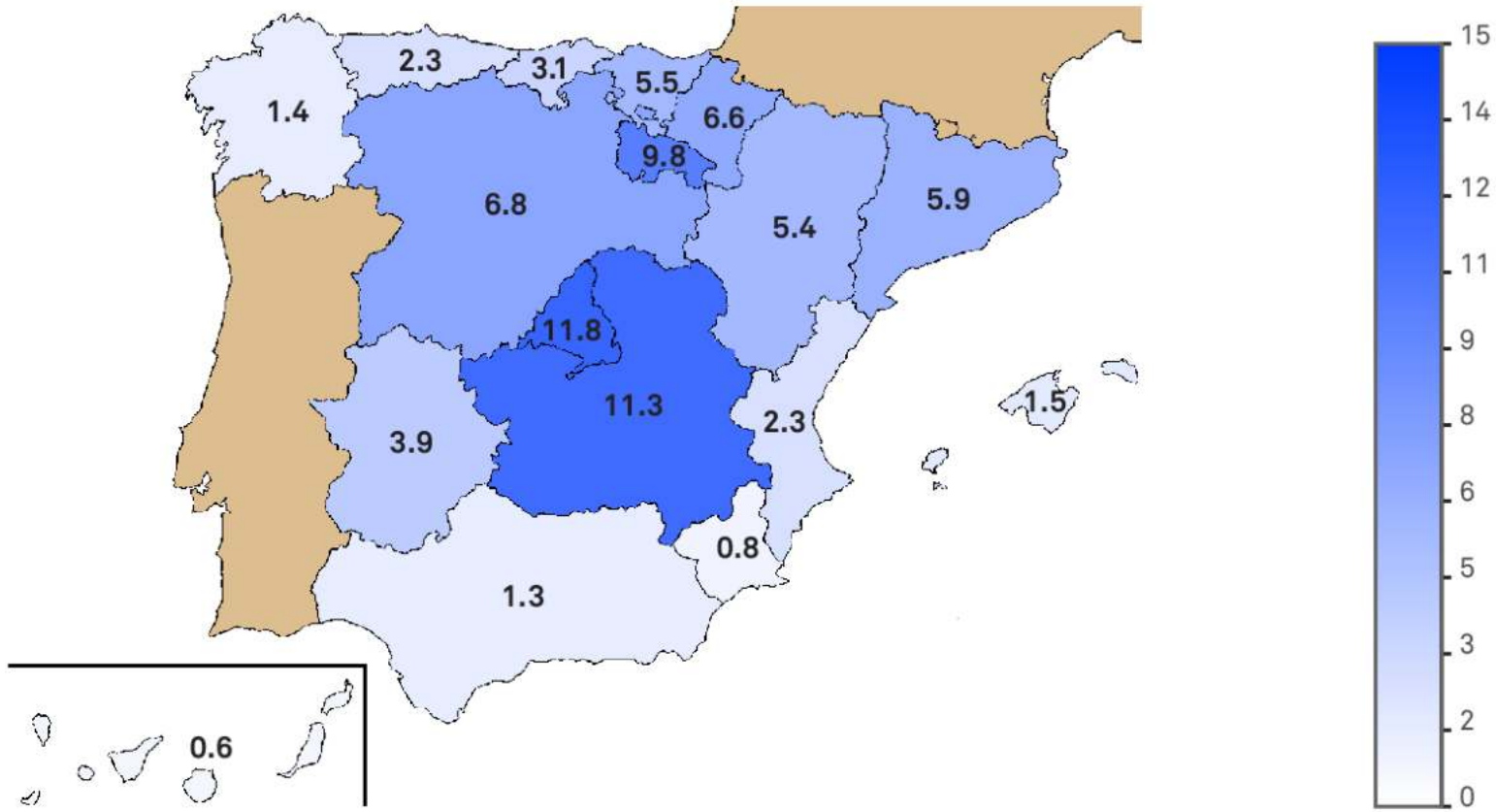


Table from late April

Countries	Detection Delay			Diagnosis Delay Detection Rate (%)			Estimated cumulative cases			Estimated attack rate /10^5 inh.		
	Value	min	max	Value	min	max	Value	min	max	Value	min	max
Belgium	8	4	12	4%	3%	6%	759000	596000	1060000	6553	5140	9143
France	10	5	14	5%	3%	5%	2331000	1956000	3044000	3571	2996	4663
Germany	8	4	12	27%	21%	32%	489000	412000	633000	583	492	755
Italy	14	10	14	7%	6%	7%	2352000	2352000	2631000	3889	3889	4352
Netherlands	13	9	14	7%	6%	8%	382000	362000	471000	2230	2115	2749
Portugal	14	10	14	27%	21%	27%	68000	68000	87000	668	668	852
Spain	14	12	14	9%	8%	9%	2043000	2043000	2171000	4344	4344	4617
Sweden*	9	4	14	6%	4%	8%	197000	142000	289000	1955	1406	2860
Switzerland	10	7	14	23%	21%	25%	116000	104000	127000	1335	1197	1472
United Kingdom	13	8	14	6%	4%	6%	1777000	1625000	2683000	2617	2394	3953

INDICE DE SEROPREVALENCIA POR COMUNIDADES

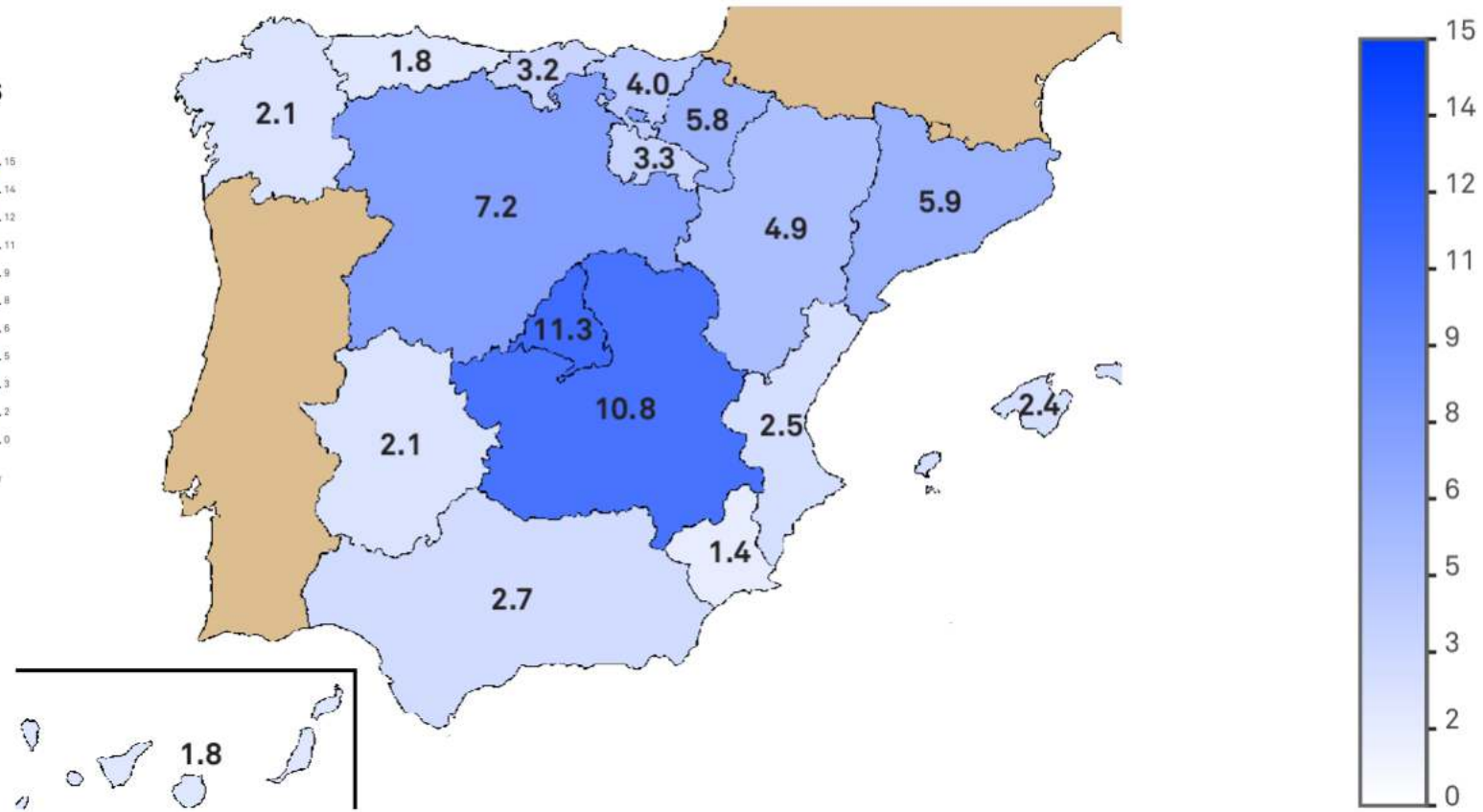
Predicción: @BIOCOMSC1



FUENTE: BIOCOM-SC UPC, CMCiB IGTP / GRAFICO: INFOGRAFIA.CAT

INDICE DE SEROPREVALENCIA POR COMUNIDADES

Datos estudio Ministerio Salud: @SALUDISCIII



FUENTE: Instituto de Salud Carlos III (ISCIII) / GRAFICO: INFOGRAFIA.CAT

Assessment of risk in Spain. A look at phase 1

CASOS ACTIVOS POR COMUNIDADES AUTÓNOMAS

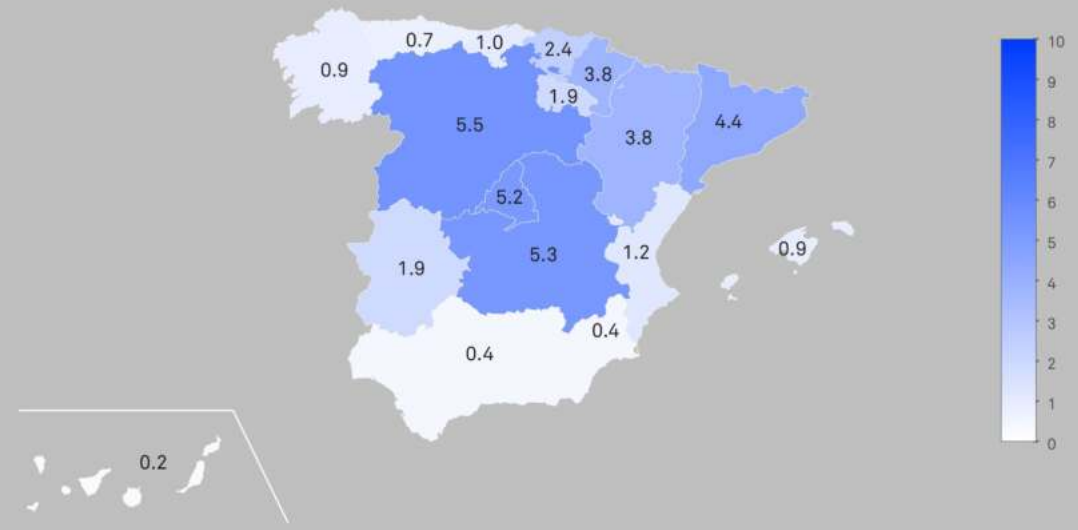
Datos a **19 de mayo**

	Estimación	% total
ANDALUCÍA *	3.500	2.82
ARAGÓN	5.000	4.02
ASTURIAS	700	0.56
ISLAS BALEARES	1.000	0.80
COMUNIDAD VALENCIANA	5.900	4.75
CANARIAS *	500	0.40
CANTABRIA	600	0.48
CASTILLA Y LEÓN	13.200	10.62
CASTILLA-LA MANCHA	10.800	8.69
CATALUÑA	34.000	27.35
EXTREMADURA	2.000	1.61
GALICIA	2.500	2.01
LA RIOJA **	600	0.48
MADRID	34.900	28.08
MURCIA	600	0.48
NAVARRA	2.500	2.01
PAÍS VASCO	5.300	4.26
ESPAÑA	124.300	

Estimación con errores del +-15%
*Andalucía y Canarias pueden presentar un número mayor de casos activos respecto a lo indicado si se confirman los resultados de letalidad en el estudio ENE-COVID19
** La Rioja ha presentado datos de seroprevalencia en ENE-COVID19 estructuralmente muy diferentes del resto de Comunidades sin tener claro su origen.
Nuestra estimación es marcadamente diferente a dichos resultados.

CASOS ACTIVOS POR MIL HABITANTES

Estimación a **19 de mayo**



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Graphics design
[Ferran Caymel (@infografia_cat)]

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-Index

-Following-up deconfinement

-Early detection

Index 1: Spreading rate

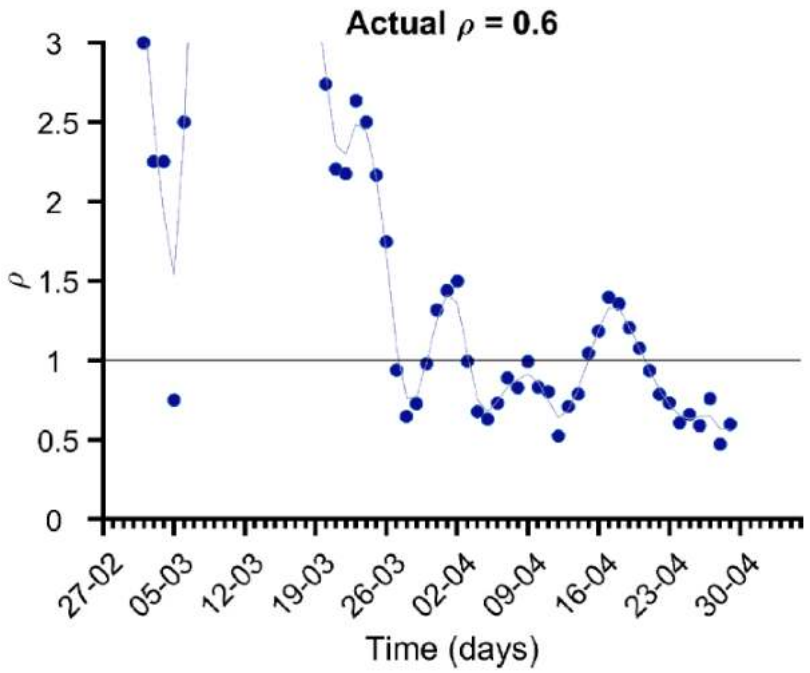
- ✓ Basic reproduction number: R_0
- ✓ Effective reproduction number: R_t

→ Estimated with SIR models

Empirical evaluation of spreading rate: ρ_t

$$\rho_t = \frac{N_{new}(t+1) + N_{new}(t) + N_{new}(t-1)}{N_{new}(t-4) + N_{new}(t-5) + N_{new}(t-6)}$$

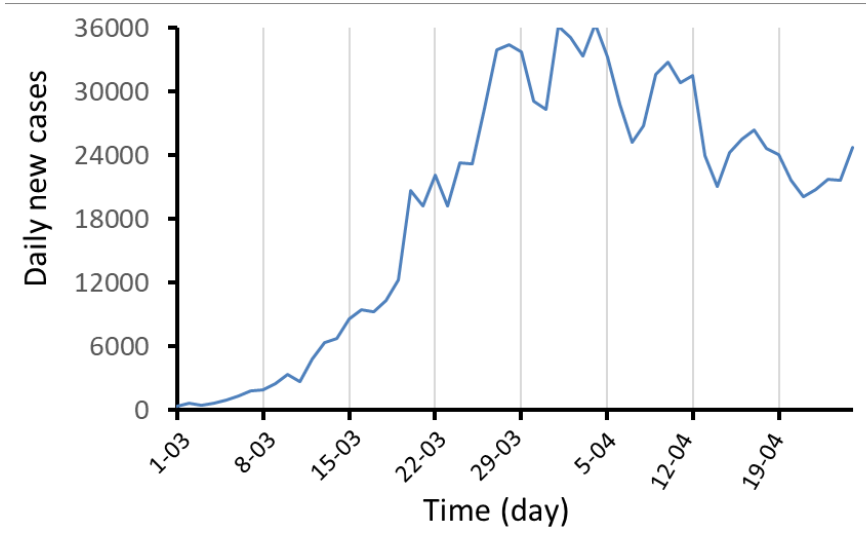
Catalunya, 01-05-2020

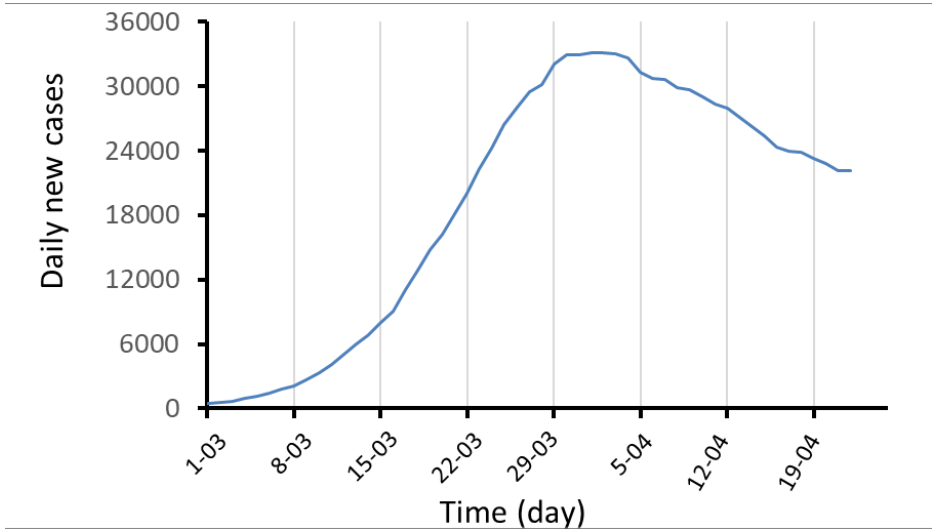


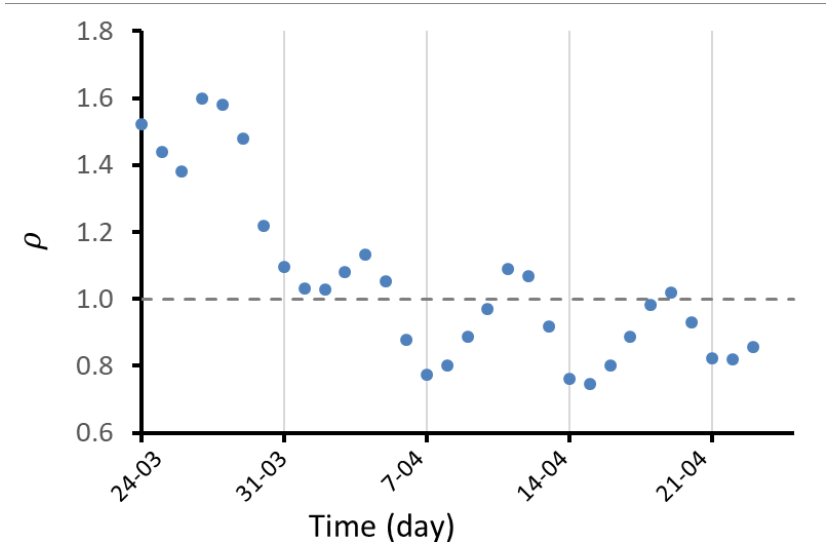
Index 1: Spreading rate and weekend effect

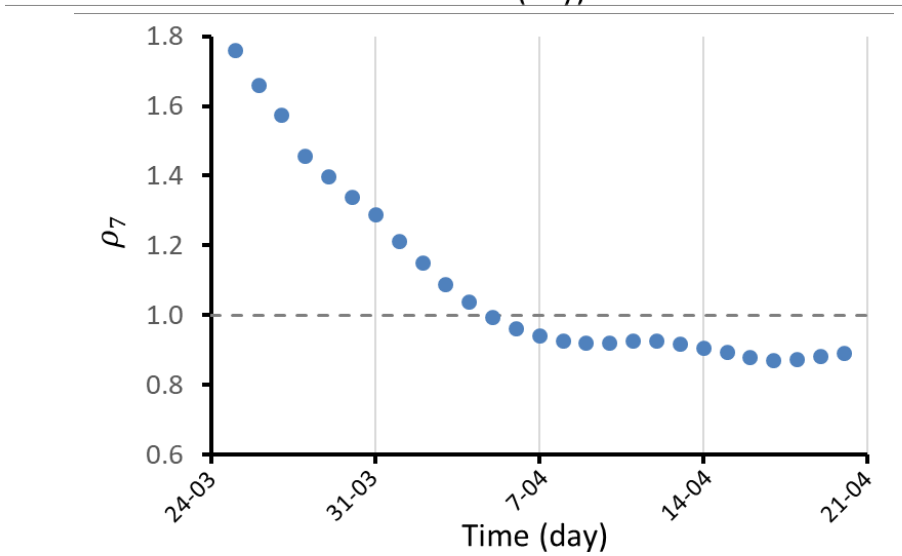
EU+EFTA+UK: weekend effect

Daily data







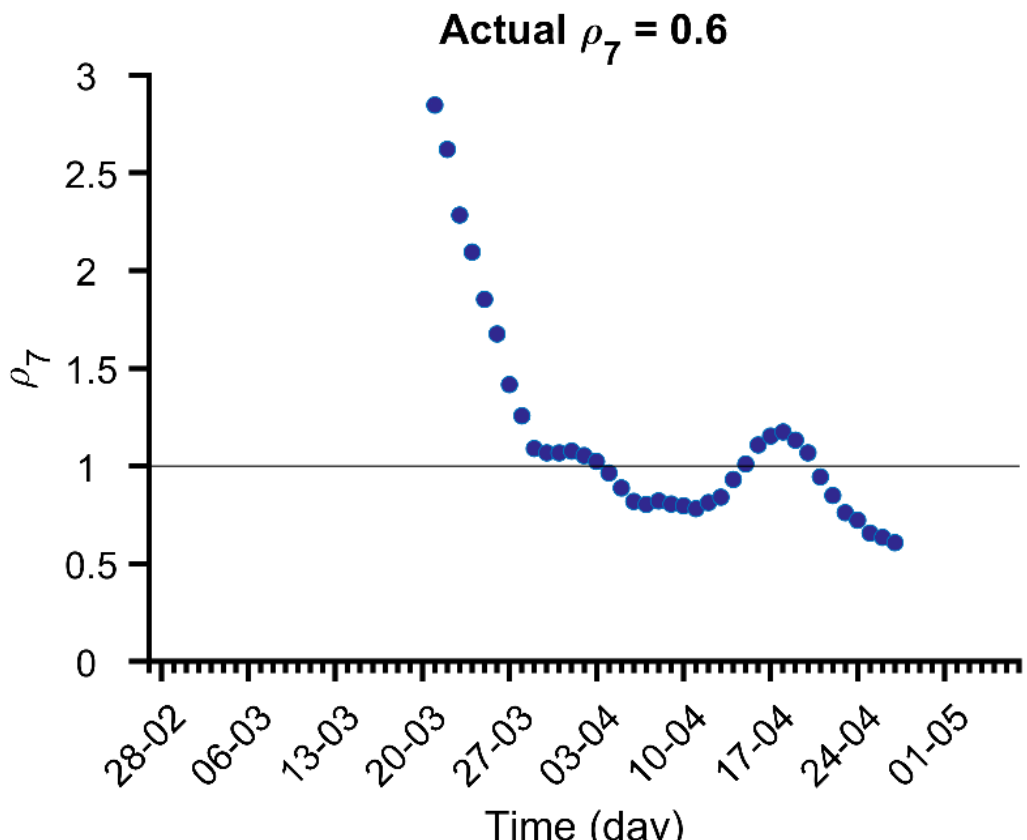


7-day moving average

Index 1: Spreading rate

Empirical evaluation of spreading rate: $\rho_t \rightarrow \rho_7$

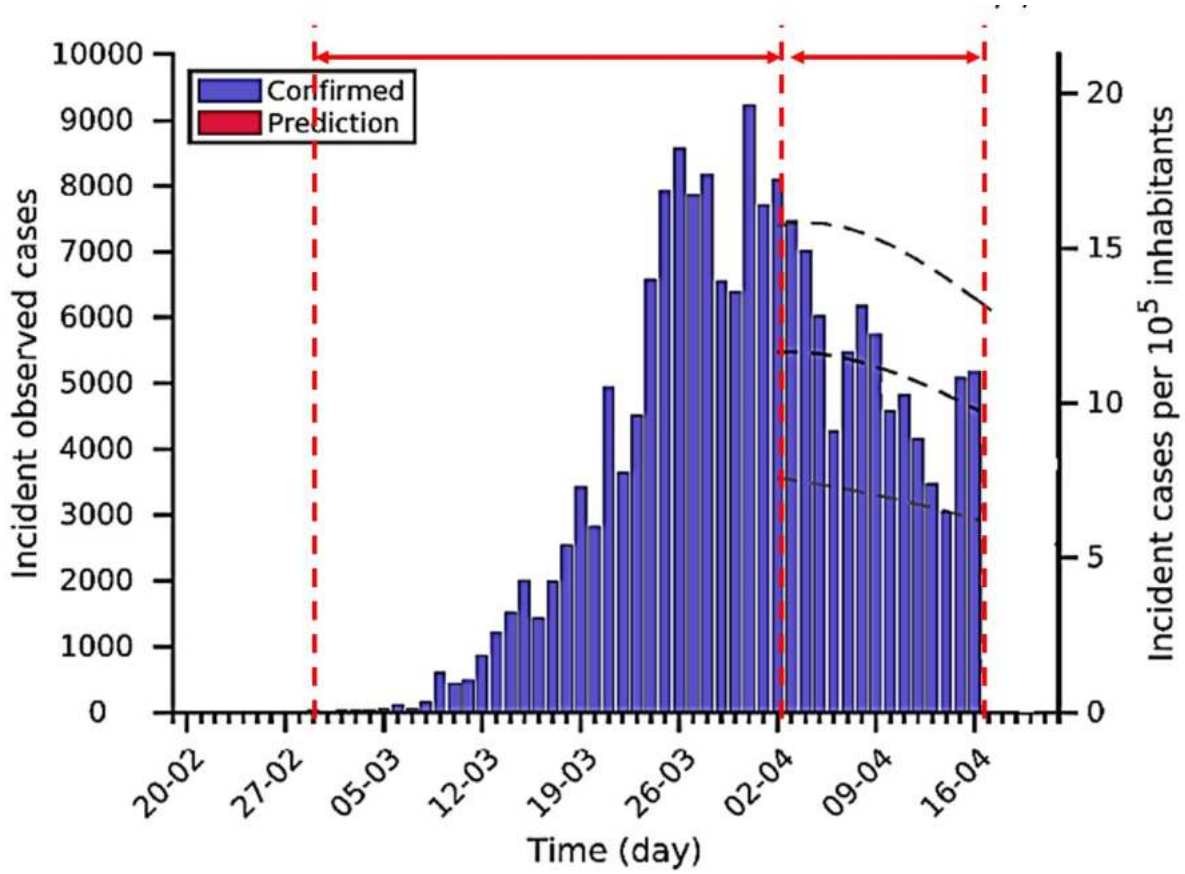
$$\rho_7 = \frac{\rho(t-3) + \rho(t-2) + \rho(t-1) + \rho(t) + \rho(t+1) + \rho(t+2) + \rho(t+3)}{7}$$



Catalunya, 01-05-2020

Index 2: 14-day attack rate

- ✓ 14-day cumulative incidence (14-day attack rate, A_{14}) is used as an indicator of **active cases** (ECDC, Ministerio…).



Infectious pool → Contagious potential at spreading rate ρ

Index 3: Effective Potential Growth (EPG)

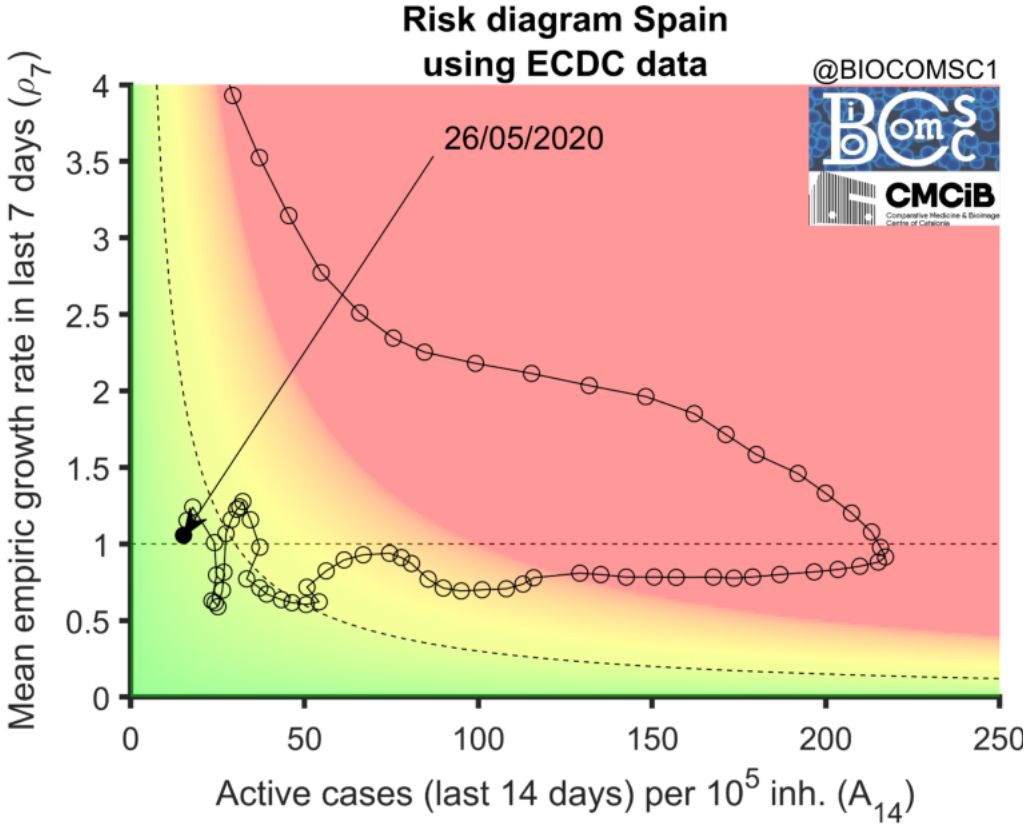
Effective potential growth is given by:

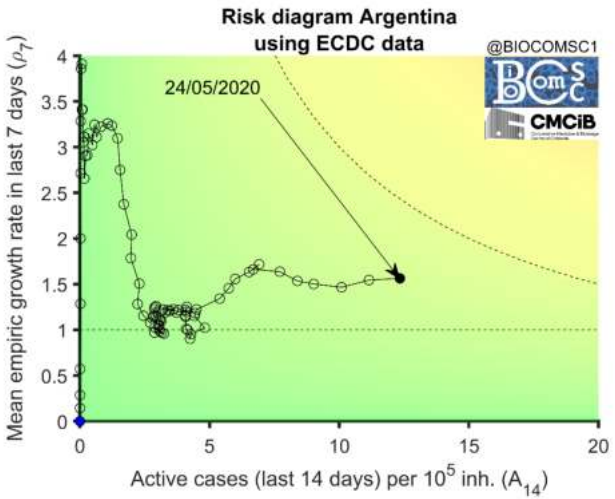
- Spreading rate ρ (ρ_7)
- Active cases (A_{14})

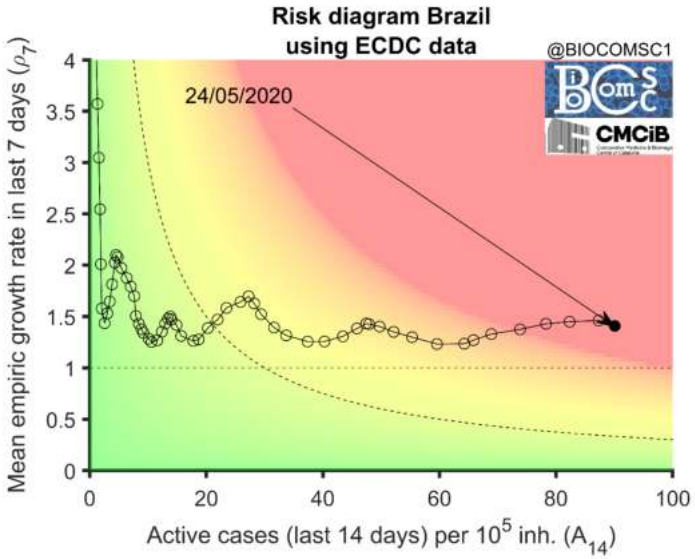
$$EPG = \rho_7 \cdot A_{14}$$

	Reported data						Indexes		
Country	Cumulative cases	Attack rate /10^5 inh.	Cumulative deaths	Mortality /10^5 inh.	Active cases (last 14 days)	14-day attack rate /10^5 inh.	ρ_7 (1)	EPG_{REP} (2)	EPG_{EST} (3)
Spain	216,582	467.3	25,100	54.2	30,150	65.1	0.69	45	552
Italy	209,328	352.2	28,710	48.3	33,403	56.2	0.79	44	623
United Kingdom	182,260	274.3	28,131	42.3	68,043	102.4	1.02	104	1,780
Germany	162,496	198.4	6,649	8.1	22,599	27.6	0.67	18	86
France	130,979	202.4	24,760	38.3	19,158	29.6	0.69	20	410
Belgium	49,517	436.0	7,765	68.4	12,334	108.6	0.65	71	1,182
Netherlands	40,236	236.9	4,987	29.4	8,647	50.9	0.64	33	422
Switzerland	29,734	347.0	1,466	17.1	2,412	28.1	0.75	21	110
Portugal	25,190	242.9	1,023	9.9	5,505	53.1	0.66	35	154
Sweden	22,082	224.5	2,669	27.1	8,260	84.0	0.98	83	1,400
Ireland	21,176	448.1	1,265	26.8	6,418	135.8	0.74	100	707
Austria	15,558	178.6	596	6.8	896	10.3	0.97	10	39
Poland	13,375	35.0	664	1.7	4,633	12.1	0.94	11	69
Romania	12,732	64.4	771	3.9	4,314	21.8	0.94	20	143
Denmark	9,407	164.7	475	8.3	2,165	37.9	0.89	34	182
Norway	7,759	144.5	204	3.8	775	14.4	0.76	11	31
Czech Republic	7,755	73.1	245	2.3	1,101	10.4	0.79	8	28
Finland	5,179	94.1	220	4.0	1,498	27.2	0.87	24	123
Luxembourg	3,812	661.8	92	16.0	275	47.7	0.74	35	ND
Hungary	2,998	30.7	340	3.5	1,082	11.1	0.87	10	136
Greece	2,620	23.4	143	1.3	413	3.7	0.61	2	14
Croatia	2,088	49.6	77	1.8	256	6.1	0.55	3	ND
Iceland	1,798	493.6	10	2.7	38	10.4	0.50	5	ND
Estonia	1,699	129.5	53	4.0	187	14.3	0.79	11	ND
Bulgaria	1,594	22.4	72	1.0	716	10.0	1.10	11	ND
Slovenia	1,439	69.2	94	4.5	122	5.9	0.87	5	ND
Slovakia	1,407	25.8	24	0.4	318	5.8	0.30	2	ND
Lithuania	1,406	48.3	46	1.6	108	3.7	NA	NA	NA
Latvia	871	44.2	16	0.8	159	8.1	0.91	7	ND
Cyprus	864	73.8	20	1.7	103	8.8	1.10	10	ND
Malta	467	108.9	4	0.9	41	9.6	ND	ND	ND
Liechtenstein	83	215.3	1	2.6	1	2.6	ND	ND	ND

Following up on deconfinement: Risk diagrams







Following up on deconfinement: How to define high risk. Red colour

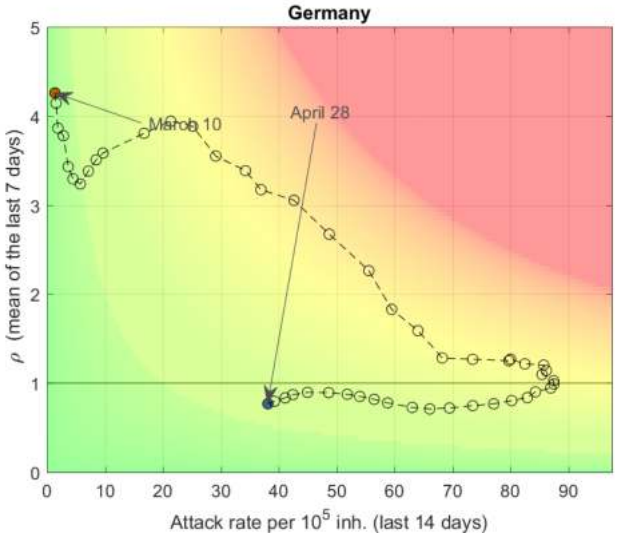
DTL: Daily PCR tests performed per 100.000 people.

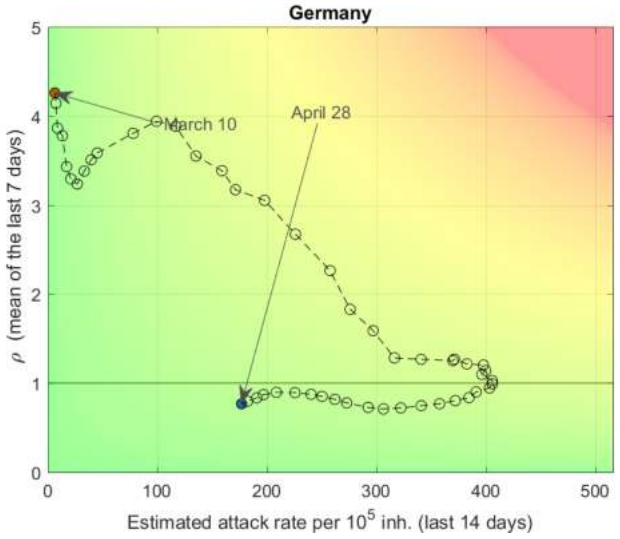
Country	Population (M)	Daily tests*	DTL	DR (%)	IA14 (rep.)	IA14 (est.)	TCF=DTL/IA14e
USA	328	320.000	100	15*	88	590	0.17
Italy	60	60.000	100	7	26	370	0.27
Spain	47	40.000	85	8	23	290	0.29
France	67	24.000	35	5	18	360	0.10
Germany	83	67.000	80	20	15	75	1.01
UK	66.5	65.000	100	7	87	1240	0.08
Denmark	6	15.000	250	20	26	130	1.92
South Korea	51.5	15.000	30	40*	5	12	2.5
Israel	9	15.000	165	60*	4	7	23.6

If there are 1000-2000 active cases per 100.000 people with DTL=100 it is impossible to control the epidemics by contact tracing

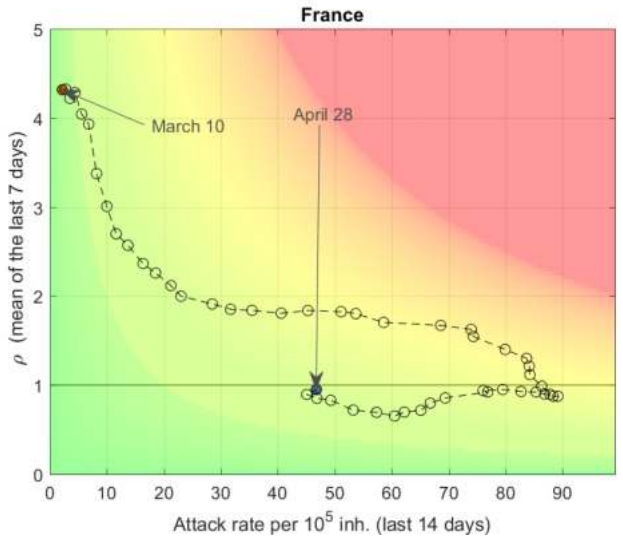
Following up on deconfinement: Risk diagrams. Reported vs estimated.

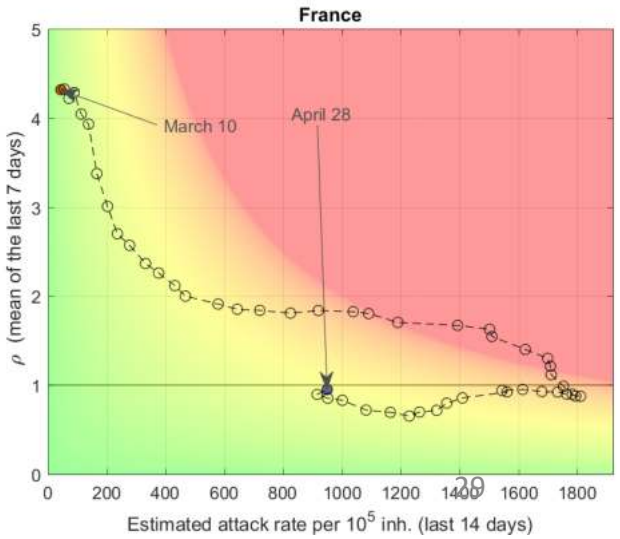
Germany: real situation better than reported



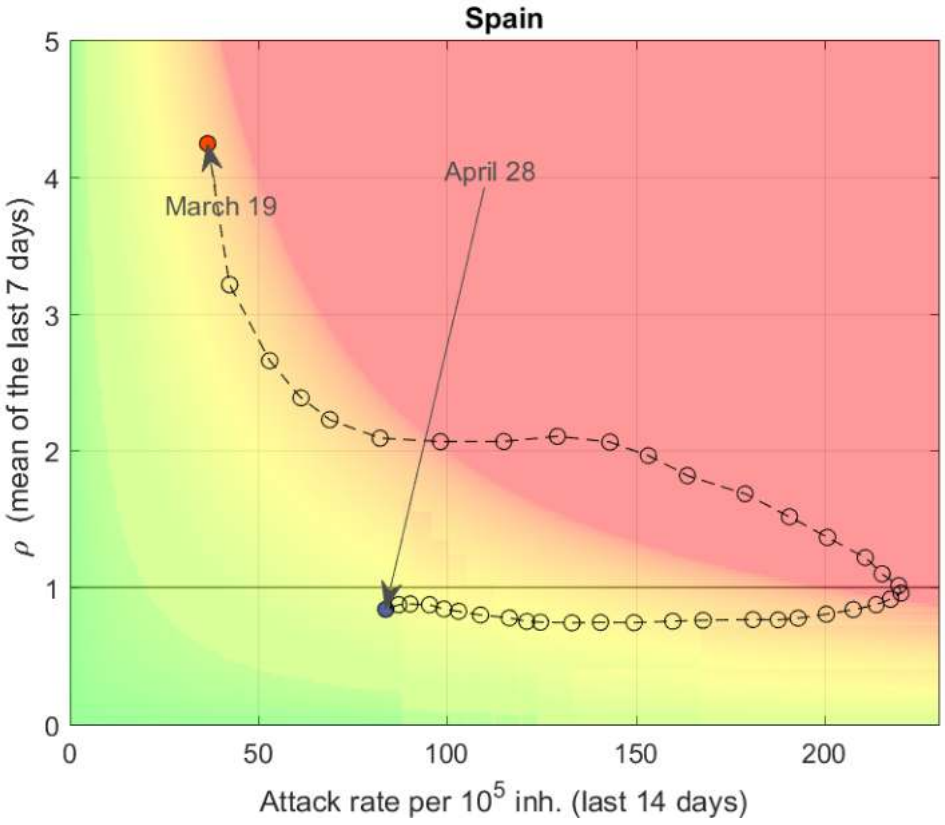


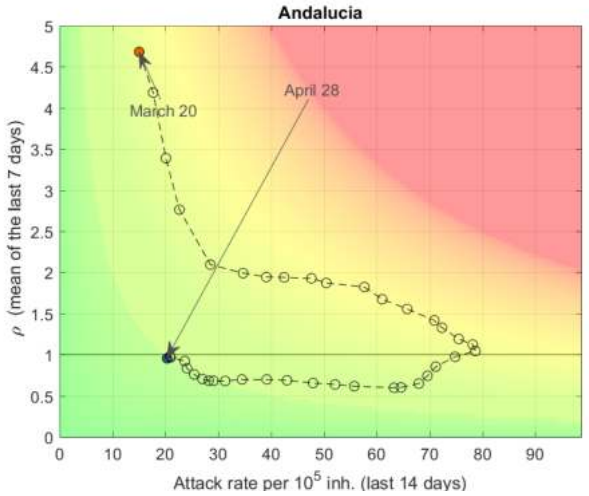
France: real situation worse than reported

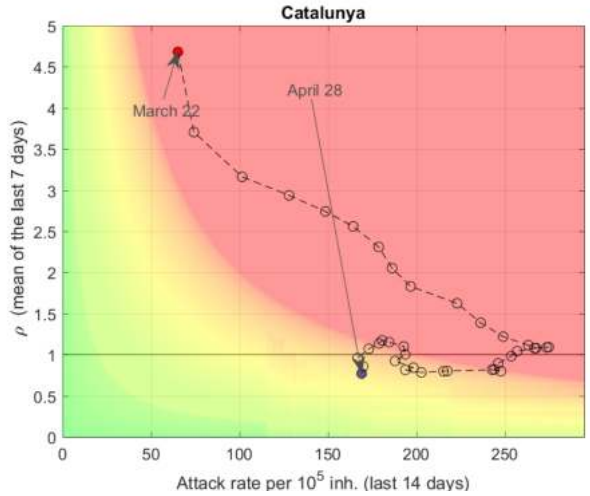


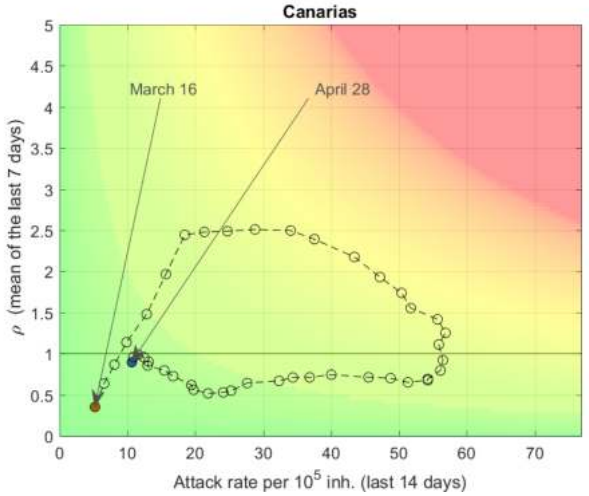


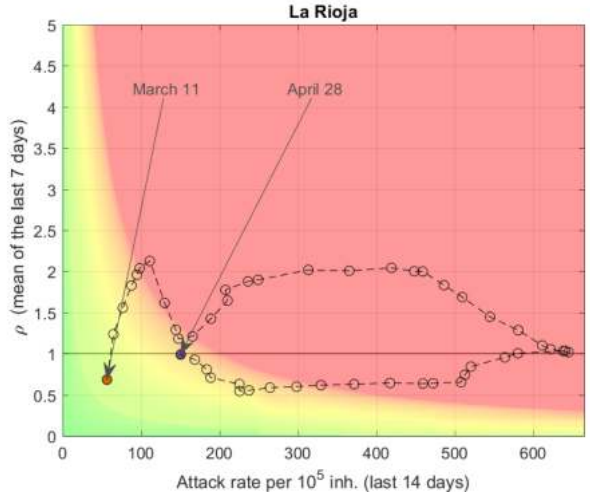
Following up on deconfinement: Risk diagrams. The importance of the region.











Provinces? Sanitary regions? Lower level?

Early detection. Dashboard for Italian provinces

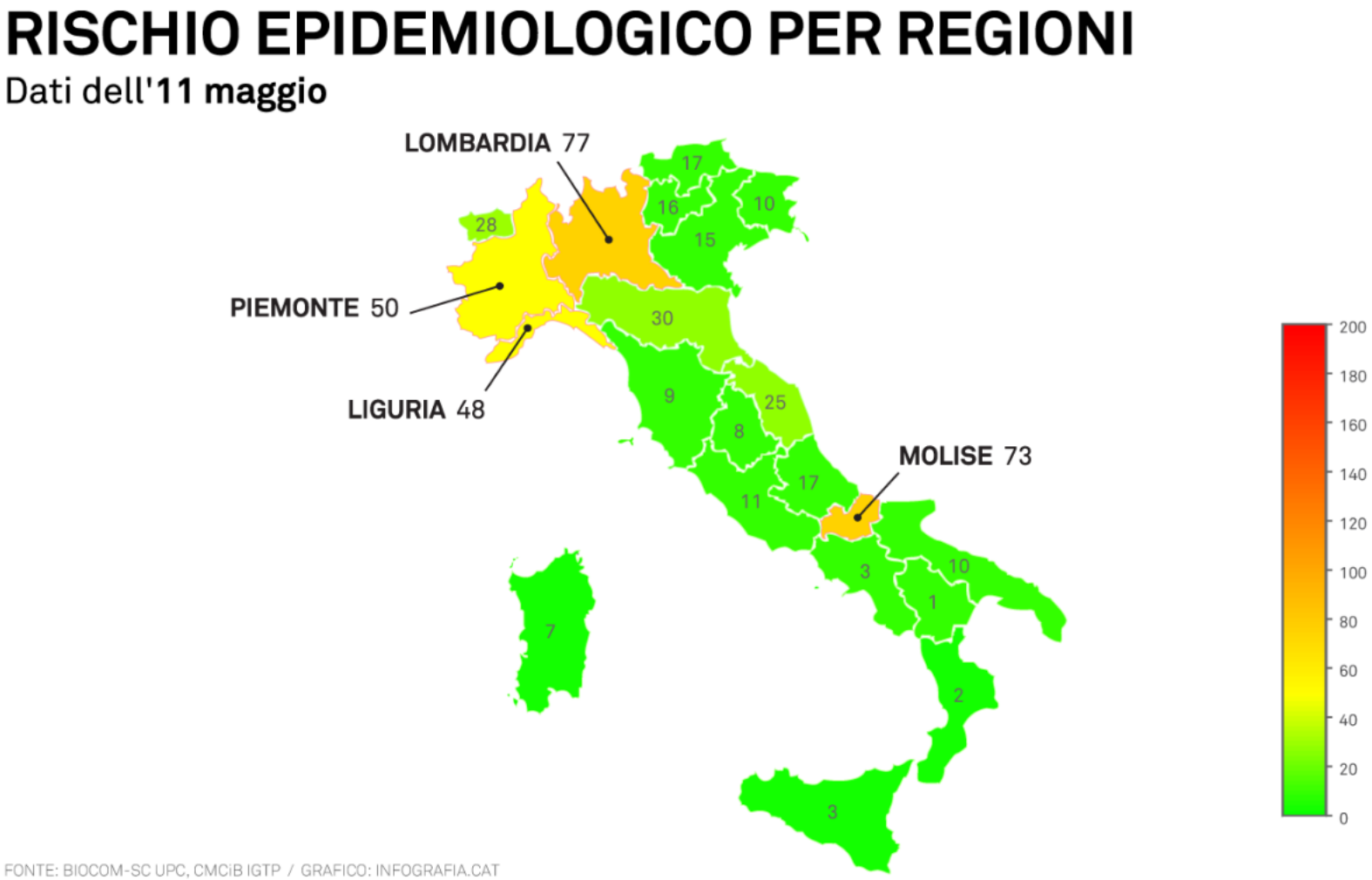
	Abruzzo			Basilicata			Bolzano			Calabria			Campania		
	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG
01-04-20	1.31	89	117	1.49	37	56	1.31	970	1269	1.57	28	43	1.45	31	44
02-04-20	1.23	85	104	1.4	37	52	1.29	971	1252	1.46	27	39	1.53	31	47
03-04-20	1.06	85	90	1.28	37	48	1.25	941	1173	1.27	27	34	1.53	33	51
04-04-20	0.93	84	78	1.08	35	38	1.12	904	1012	0.99	26	26	1.5	34	51
05-04-20	0.73	85	62	0.81	35	28	0.93	899	840	0.76	27	20	1.4	35	49
06-04-20	0.68	81	55	0.64	35	22	0.79	929	737	0.7	27	19	1.24	35	44
07-04-20	0.71	85	60	0.62	35	22	0.79	959	758	0.85	26	22	1.08	35	38
08-04-20	0.78	80	63	0.61	33	20	0.8	909	732	0.93	26	24	0.97	36	34
09-04-20	0.87	75	66	0.63	30	19	0.87	928	803	1.01	25	25	0.85	35	30
10-04-20	0.95	76	73	0.63	28	18	0.9	886	800	1.06	21	22	0.75	34	26
11-04-20	1.11	75	83	0.65	23	15	0.93	789	736	1.09	18	20	0.67	33	22
12-04-20	1.19	66	79	0.61	20	12	0.97	823	798	1.02	16	16	0.64	32	20
13-04-20	1.21	66	80	0.59	19	11	1	767	768	0.86	14	12	0.63	30	19
14-04-20	1.14	64	73	0.53	17	9	0.98	757	739	0.66	15	10	0.67	29	19
15-04-20	1.08	64	69	0.49	15	7	0.96	750	718	0.64	16	10	0.69	27	19
16-04-20	0.99	65	64	0.57	16	9	0.95	733	694	0.74	16	12	0.75	25	18
17-04-20	0.97	67	65	0.71	14	10	0.9	686	620	0.74	13	10	0.76	22	17
18-04-20	0.88	65	58	0.87	13	12	0.87	682	594	0.86	14	12	0.78	20	16
19-04-20	0.89	62	56	0.93	11	11	0.81	685	558	0.87	12	11	0.75	18	14
20-04-20	0.92	68	63	0.99	10	10	0.78	625	488	0.95	11	11	0.73	18	13
21-04-20	1.03	66	68	1.02	10	11	0.7	558	393	0.92	11	10	0.7	17	12
22-04-20	1.11	67	74	1.08	10	11	0.63	541	338	0.92	10	9	0.72	16	11
23-04-20	1.15	65	75	1.02	9	10	0.55	495	270	0.82	10	8	0.73	15	11
24-04-20	1.14	60	68	1.04	9	10	0.52	466	243	0.89	9	8	0.78	14	11
25-04-20	1.07	54	58	1	9	9	0.53	483	258	0.77	9	7	0.8	13	11
26-04-20	0.93	53	49	1	9	9	0.54	356	193	0.76	9	6	0.81	13	10
27-04-20	0.76	50	38	0.93	8	8	0.59	323	190	0.71	9	6	0.78	12	9
28-04-20	0.63	50	31	0.89	8	7	0.56	292	164	0.69	7	5	0.75	11	8
29-04-20	0.54	49	27	0.8	8	7	0.6	263	157	0.65	7	4	0.71	10	7
30-04-20	0.5	45	22	0.71	6	4	0.59	234	138	0.6	5	3	0.67	9	6
01-05-20	0.49	39	19	0.64	7	5	0.63	216	135	0.53	6	3	0.62	8	5
02-05-20	0.49	36	18	0.78	7	6	0.64	195	125	0.53	5	3	0.59	8	5
03-05-20	0.57	36	21	1.19	8	9	0.68	145	99	0.54	4	2	0.61	8	5
04-05-20	0.64	30	19	1.83	8	14	0.59	137	81	0.51	4	2	0.65	7	5
05-05-20	0.74	27	20	2.5	8	20	0.56	123	69	0.55	4	2	0.69	7	5
06-05-20	0.82	24	20	2.65	8	21	0.51	118	61	0.57	3	2	0.72	6	4
07-05-20	0.99	22	22	2.6	5	12	0.52	109	56	0.61	3	2	0.75	5	4
08-05-20	1.01	21	21	2.32	4	9	0.55	95	52	0.67	2	2	0.76	5	4
09-05-20	1.03	19	20	1.69	4	6	0.71	85	60	0.75	2	2	0.77	5	4
10-05-20	0.97	19	18	1.16	3	4	0.94	82	77	0.8	2	2	0.78	4	3
11-05-20	0.93	18	17	0.49	4	2	1.16	71	82	0.88	2	2	0.8	4	3
12-05-20	0.83	16	14	-0.46	4	-2	1.18	69	81	0.98	2	2	0.81	4	3
13-05-20	0.75	16	12	-0.66	4	-3	1.2	63	76	1.07	2	2	0.84	4	3
14-05-20	0.6	16	9	-0.65	4	-3	1.18	56	66	1.15	2	2	0.84	4	3
15-05-20	0.64	15	10	-0.4	2	-1	1.1	47	51	1.11	2	2	0.85	4	3
16-05-20	0.79	16	13	-0.06	2	0	0.87	40	35	1.14	2	2	0.87	4	3
17-05-20	0.96	14	14	0	1	0	0.61	42	25	1.12	2	2	0.92	3	3
18-05-20	1.15	15	17	0.07	1	0	0.42	38	16	1.1	2	2	0.94	3	3
19-05-20	1.18	13	16	0.45	-1	0	0.57	42	24	0.95	2	2	0.97	3	3
20-05-20	1.2	12	14	0.56	-1	-1	0.65	41	27	0.91	2	2	0.94	3	3
21-05-20	1.15	11	12	0.87	2	2	0.86	33	28	0.79	2	1	0.92	3	3
22-05-20	1.06	11	11	0.78	2	2	0.95	30	28	0.74	2	1	0.89	3	3
23-05-20	0.86	10	9	0.98	3	3	1.03	21	22	0.56	1	1	0.86	3	2
24-05-20	0.72	9	7	1.13	2	3	1.04	22	23	0.5	1	1	0.79	3	2
25-05-20	0.5	9	5	1.74	2	4	1.01	20	20	0.38	1	0	0.75	3	2
26-05-20	0.48	9	4	1.67	2	4	0.88	20	17	0.35	1	0	0.72	3	2

	Emilia Romagna			Friuli Venezia Giulia			Lazio			Liguria			Lombardia		
	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG
01-04-20	0.87	230	200	0.9	101	90	1.1	43	48	0.91	179	162	0.87	269	234
02-04-20	0.83	227	188	0.91	99	90	1.05	44	47	0.9	176	158	0.84	261	218
03-04-20	0.8	223	180	0.9	101	91	1.03	44	45	0.91	177	162	0.81	252	203
04-04-20	0.8	221	177	0.98	98	97	0.98	44	43	0.96	178	171	0.78	235	184
05-04-20	0.82	214	176	1.03	97	99	0.93	42	39	1.01	180	182	0.78	232	180
06-04-20	0.85	202	172	1.09	97	105	0.87	42	37	1.04	169	176	0.79	227	180
07-04-20	0.85	192	163	1.09	96	104	0.82	41	34	1.05	170	178	0.82	215	177
08-04-20	0.83	183	153	1.08	89	96	0.79	40	32	1.02	168	171	0.84	210	176
09-04-20	0.81	176	143	1.03	89	91	0.78	40	31	0.99	158	156	0.87	198	172
10-04-20	0.8	169	136	0.99	85	84	0.8	39	31	0.93	161	149	0.89	187	166
11-04-20	0.8	163	130	0.86	79	68	0.84	38	32	0.89	165	147	0.91	181	165
12-04-20	0.81	156	126	0.75	78	59	0.88	36	32	0.86	156	133	0.93	180	168
13-04-20	0.83	155	129	0.71	81	57	0.92	35	32	0.84	153	129	0.99	181	179
14-04-20	0.87	150	131	0.72	76	55	0.95	34	33	0.83	154	128	1.03	180	187
15-04-20	0.89	140	124	0.72	71	51	0.97	33	32	0.86	147	126	1.05	173	183
16-04-20	0.9	138	124	0.73	67	49	0.98	33	32	0.87	146	126	1.04	170	177
17-04-20	0.9	132	120	0.79	66	52	0.98	33	32	0.89	143	128	1.02	165	168
18-04-20	0.91	127	115	0.88	61	54	0.99	33	32	0.9	135	122	0.98	162	158
19-04-20	0.89	123	109	0.91	57	52	0.98	32	31	0.94	134	126	0.91	157	142
20-04-20	0.88	119	105	0.92	55	51	0.94	30	29	0.97	137	133	0.83	154	128
21-04-20	0.86	118	102	0.9	53	47	0.88	30	26	0.99	129	128	0.8	155	124
22-04-20	0.88	117	102	0.88	49	43	0.83	29	24	0.99	130	129	0.82	156	129
23-04-20	0.88	113	99	0.83	46	38	0.78	28	22	1.01	131	132	0.87	153	133
24-04-20	0.88	109	96	0.77	44	34	0.73	26	19	1.01	128	129	0.93	151	141
25-04-20	0.87	103	89	0.69	42	29	0.69	26	18	1	124	124	0.96	143	138
26-04-20	0.84	98	82	0.68	40	27	0.71	25	18	0.97	129	125	1	138	137
27-04-20	0.8	95	75	0.74	41	30	0.77	24	19	0.99	132	130	0.98	131	128
28-04-20	0.79	93	74	0.84	39	33	0.84	23	19	1.01	127	128	0.95	130	124
29-04-20	0.79	93	74	0.92	38	35	0.91	22	20	1.01	126	127	0.9	129	117
30-04-20	0.83	89	74	0.93	34	31	0.96	21	20	0.99	126	125	0.87	126	110
01-05-20	0.86	85	73	0.95	30	29	0.98	20	19	0.98	125	123	0.83	123	103
02-05-20	0.89	82	73	0.9	27	24	0.98	19	18	1	130	130	0.81	116	94
03-05-20	0.89	77	69	0.83	27	22	0.93	18	17	0.97	118	115	0.77	112	86
04-05-20	0.88	74	65	0.7	25	17	0.87	18	15	0.9	112	102	0.76	111	84
05-05-20	0.84	71	60	0.62	24	15	0.82	17	14	0.79	110	88	0.75	106	80
06-05-20	0.8	66	53	0.54	23	12	0.81	17	14	0.73	105	77	0.78	102	80
07-05-20	0.72	62	45	0.55	20	11	0.81	17	13	0.68	103	70	0.82	99	81
08-05-20	0.66	59	39	0.53	19	10	0.82	16	13	0.66	100	66	0.88	94	83
09-05-20	0.61	56	34	0.58	18	11	0.82	15	13	0.63	93	58	0.92	92	85
10-05-20	0.59	53	31	0.63	18	11	0.82	15	12	0.64	84	54	0.94	86	81
11-05-20	0.6	50	30	0.72	13	10	0.8	14	11	0.62	77	48	0.92	84	77
12-05-20	0.62	45	28	0.76	13	10	0.75	13	10	0.63	70	44	0.94	85	80
13-05-20	0.63	40	25	0.81	12	10	0.7	12	8	0.63	67	43	0.94	81	76
14-05-20	0.64	36	23	0.83	11	9	0.67	11	8	0.68	65	44	0.94	81	76
15-05-20	0.64	33	21	0.9	11	10	0.71	12	8	0.78	60	47	0.89	76	68
16-05-20	0.65	30	20	0.95	10	10	0.8	11	9	0.92	52	48	0.88	75	66
17-05-20	0.67	27	18	1	10	10	0.96	11	10	0.99	52	51	0.84	73	61
18-05-20	0.68	24	17	0.99	10	10	1.09	11	12	1.04	50	52	0.82	69	57
19-05-20	0.69	23	16	1	10	10	1.18	10	12	1.09	50	55	0.77	68	53
20-05-20	0.71	22	16	0.98	9	9	1.19	9	11	1.1	48	52	0.76	64	49
21-05-20	0.74	21	16	0.96	9	9	1.16	9	10	1.1	45	49	0.74	60	44
22-05-20	0.79	20	15	0.9	9	8	1.07	9	9	1.01	43	44	0.74	56	42
23-05-20	0.82	18	15	0.88	9	8	0.96	8	8	0.93	44	41	0.76	56	42
24-05-20	0.85	17	15	0.85	9	7	0.77	8	6	0.87	45	39	0.82	56	46
25-05-20	0.86	16	14	0.83	8	7	0.65	8	5	0.86	43	37	0.88	54	47
26-05-20	0.84	15	13	0.85	8	7	0.6	8	5	0.85	44	38	0.89	45	40

	Marche			Molise			Piemonte			Puglia			Sardegna		
	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG
01-04-20	0.82	157	129	1.84	43	80	1.05	171	180	1.13	39	44	1.29	37	48
02-04-20	0.83	155	128	1.78	39	69	1.02	170	175	1.14	40	45	1.28	36	46
03-04-20	0.86	147	127	1.71	41	70	1.01	171	172	1.14	40	45	1.26	32	41
04-04-20	0.86	143	124	1.55	47	74	1.01	183	185	1.09	39	42	0.99	33	33
05-04-20	0.87	134	117	1.67	52	86	1.05	182	192	1.03	38	39	0.93	35	32
06-04-20	0.87	134	117	1.37	51	70	1.09	185	202	0.95	38	36	0.85	34	29
07-04-20	0.88	129	114	1.36	49	67	1.09	180	196	0.87	37	33	0.82	31	26
08-04-20	0.89	126	113	1.24	50	62	1.08	180	196	0.82	38	31	0.78	33	25
09-04-20	0.89	121	107	1.19	43	51	1.06	183	195	0.81	38	31	0.8	32	26
10-04-20	0.9	124	112	1.04	44	46	1.04	182	190	0.84	37	31	0.86	33	28
11-04-20	0.92	121	111	0.84	40	34	1.02	191	196	0.88	36	31	0.91	28	26
12-04-20	0.94	114	108	0.62	43	26	1.04	194	201	0.92	36	33	0.95	29	28
13-04-20	0.91	111	102	1.13	40	45	1.05	193	203	0.94	34	32	0.96	27	26
14-04-20	0.88	105	92	1.2	37	44	1.06	193	204	0.94	33	31	0.95	25	24
15-04-20	0.81	101	82	1.24	34	42	1.06	194	205	0.92	31	28	0.91	25	23
16-04-20	0.77	97	75	1.25	32	40	1.07	201	215	0.89	29	26	0.84	23	19
17-04-20	0.72	94	68	1.28	30	39	1.09	204	224	0.82	28	23	0.74	22	16
18-04-20	0.69	90	63	1.28	21	26	1.1	201	220	0.8	29	23	0.65	20	13
19-04-20	0.68	86	59	1.3	18	23	1.07	200	214	0.84	30	25	0.6	19	11
20-04-20	0.69	79	55	0.87	19	16	1.02	193	196	0.9	28	25	0.61	19	11
21-04-20	0.71	77	54	1.03	19	19	0.97	198	192	0.95	28	26	0.7	18	13
22-04-20	0.73	70	51	1.04	19	20	0.95	203	194	0.99	27	27	0.76	17	13
23-04-20	0.73	65	47	1.07	16	18	0.93	198	185	1.06	28	30	0.82	14	11
24-04-20	0.74	62	46	1.04	14	15	0.93	202	188	1.09	27	29	0.81	12	10
25-04-20	0.76	56	42	1.07	15	16	0.94	193	181	1.07	25	27	0.8	11	9
26-04-20	0.78	53	41	1	13	13	0.93	187	174	0.96	24	23	0.74	10	8
27-04-20	0.76	49	37	0.97	13	12	0.9	183	164	0.84	22	19	0.71	9	7
28-04-20	0.78	49	38	0.9	13	12	0.87	178	155	0.72	21	15	0.63	9	6
29-04-20	0.78	46	36	0.87	11	10	0.84	175	147	0.63	21	13	0.59	8	5
30-04-20	0.83	44	36	0.83	11	10	0.82	165	136	0.54	20	11	0.56	8	4
01-05-20	0.8	40	32	0.82	10	8	0.79	158	125	0.56	19	11	0.65	8	5
02-05-20	0.81	38	31	0.79	10	8	0.78	154	121	0.65	18	12	0.72	7	5
03-05-20	0.75	36	27	0.74	7	5	0.78	146	114	0.72	15	11	0.87	6	6
04-05-20	0.79	35	28	0.63	7	4	0.8	144	116	0.77	15	11	0.81	5	4
05-05-20	0.77	34	26	0.39	6	2	0.79	134	106	0.78	14	11	0.77	5	4
06-05-20	0.82	33	27	0.51	7	3	0.77	119	92	0.79	12	9	0.7	4	3
07-05-20	0.83	33	27	0.61	7	4	0.73	115	83	0.83	10	8	0.67	4	3
08-05-20	0.9	29	26	1.29	13	17	0.7	104	73	0.85	9	8	0.59	4	3
09-05-20	0.89	29	25	1.94	18	35	0.64	95	61	0.89	9	8	0.98	4	4
10-05-20	0.92	28	26	2.57	24	62	0.61	88	54	1	9	9	1.45	4	5
11-05-20	0.9	27	25	3.14	28	89	0.59	84	50	1.1	9	10	2.11	4	8
12-05-20	0.91	26	23	3.86	29	112	0.62	79	49	1.13	9	10	2.28	4	8
13-05-20	0.86	25	21	3.88	34	132	0.65	73	48	1.13	8	9	2.34	3	8
14-05-20	0.84	23	20	3.81	34	131	0.7	67	47	1.05	7	7	2.32	3	7
15-05-20	0.77	23	17	3.14	35	110	0.75	61	46	0.94	7	6	2.28	2	5
16-05-20	0.76	23	17	2.45	36	87	0.8	53	43	0.76	6	5	1.82	2	4
17-05-20	0.76	23	17	1.76	36	63	0.82	49	40	0.55	6	3	1.22	2	3
18-05-20	0.81	21	17	1.12	40	44	0.8	46	37	0.44	6	3	0.65	2	1
19-05-20	0.77	19	14	0.49	40	19	0.79	45	35	0.47	6	3	0.59	2	1
20-05-20	0.7	17	12	0.39	39	15	0.8	45	36	0.55	5	3	0.6	2	1
21-05-20	0.61	16	9	0.34	39	13	0.82	43	35	0.65	4	3	0.65	2	1
22-05-20	0.57	15	8	0.37	32	12	0.85	39	33	0.87	5	4	0.65	2	1
23-05-20	0.52	14	7	0.43	27	12	0.83	36	30	1.11	4	4	0.6	1	1
24-05-20	0.5	12	6	0.51	20	10	0.8	35	28	1.34	4	5	0.48	1	0
25-05-20	0.62	11	7	0.52	16	8	0.77	33	26	1.4	3	5	0.2	1	0
26-05-20	0.76	10	8	0.58	15	9	0.75	33	25	1.41	3	5	-0.04	1	0

	Sicilia			Toscana			Trento			Umbria			Valle dAosta			Veneto		
	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG	ρ_7	IA14	EPG
01-04-20	1.09	29	31	1.15	95	109	0.87	132	115	0.94	96	91	1.83	371	678	0.95	131	124
02-04-20	0.88	29	26	1.13	102	115	0.91	138	126	0.83	90	75	1.92	361	693	0.94	135	127
03-04-20	0.78	29	23	1.14	99	113	0.99	137	136	0.72	89	64	1.95	362	705	0.93	131	122
04-04-20	0.72	29	21	1.08	98	106	1.06	134	142	0.61	85	52	1.95	346	676	0.93	127	118
05-04-20	0.7	27	19	1	96	96	1.1	124	136	0.59	81	48	1.8	333	600	0.91	124	113
06-04-20	0.68	27	18	0.9	95	85	1.07	124	132	0.61	77	47	1.55	328	510	0.9	124	112
07-04-20	0.69	25	17	0.83	93	77	1.05	127	134	0.64	70	45	0.99	346	342	0.89	122	109
08-04-20	0.71	23	17	0.78	91	71	1.04	129	134	0.67	66	44	0.96	357	345	0.9	122	110
09-04-20	0.74	21	16	0.73	89	65	1.02	132	135	0.68	56	38	0.93	366	342	0.93	122	114
10-04-20	0.78	21	16	0.72	88	64	1.02	133	136	0.67	47	32	0.91	340	311	0.99	121	120
11-04-20	0.84	20	17	0.77	84	65	1.07	137	146	0.61	39	23	0.87	311	272	1.02	119	122
12-04-20	0.9	19	17	0.86	83	72	1.09	136	149	0.52	34	17	0.82	268	220	1.04	117	122
13-04-20	0.93	18	17	0.94	80	75	1.11	135	149	0.42	30	13	0.66	273	181	1.02	113	114
14-04-20	0.94	17	16	1.01	78	79	1.06	130	138	0.36	28	10	0.62	254	156	0.97	108	105
15-04-20	0.91	16	15	1.03	75	77	1.01	126	127	0.3	26	8	0.63	260	164	0.9	102	91
16-04-20	0.87	16	14	1.07	72	77	0.93	120	112	0.31	23	7	0.67	241	162	0.81	99	81
17-04-20	0.82	15	13	1.05	70	74	0.85	118	101	0.37	18	7	0.74	218	162	0.74	100	74
18-04-20	0.79	15	12	1.01	69	70	0.73	113	82	0.5	15	8	1	259	258	0.75	99	74
19-04-20	0.77	14	11	0.93	68	63	0.74	116	86	0.67	12	8	1.28	244	312	0.81	96	77
20-04-20	0.8	14	11	0.88	67	59	0.78	116	90	1.19	11	13	1.55	225	349	0.9	93	83
21-04-20	0.89	15	13	0.83	65	54	0.87	106	92	1.3	10	13	1.51	205	310	0.97	91	88
22-04-20	0.99	14	14	0.8	62	50	0.87	97	84	1.37	8	11	1.41	195	275	1.04	88	92
23-04-20	1.08	14	15	0.73	60	43	0.89	95	85	1.39	7	10	1.3	182	236	1.06	80	85
24-04-20	1.14	14	15	0.7	58	40	0.89	90	80	1.36	7	9	1.19	176	209	1.07	78	83
25-04-20	1.16	13	15	0.69	55	38	0.92	81	75	1.29	6	8	0.85	158	134	1.01	74	75
26-04-20	1.13	13	14	0.72	51	37	0.86	78	67	1.16	6	6	0.55	147	81	0.92	69	64
27-04-20	1.06	13	13	0.72	48	35	0.95	81	77	0.7	6	4	0.41	146	60	0.79	68	54
28-04-20	0.95	12	12	0.74	46	34	0.99	82	81	0.7	7	5	0.68	137	94	0.71	67	48
29-04-20	0.84	12	10	0.74	44	32	1.07	79	85	0.94	8	7	1.03	132	136	0.65	65	43
30-04-20	0.75	12	9	0.75	38	28	1.07	77	82	1.21	7	9	1.5	125	188	0.63	61	38
01-05-20	0.68	11	8	0.74	36	26	1.06	71	75	1.47	6	9	1.7	111	189	0.6	56	34
02-05-20	0.64	11	7	0.74	35	25	1.01	70	71	1.42	6	8	1.84	50	92	0.64	52	33
03-05-20	0.63	10	7	0.73	32	23	0.98	67	65	1.35	5	7	1.88	43	81	0.69	49	33
04-05-20	0.64	10	6	0.75	29	22	0.81	62	50	1.24	5	6	1.73	44	76	0.73	46	34
05-05-20	0.65	9	6	0.73	28	20	0.71	60	43	1.14	5	6	1.45	40	58	0.74	41	30
06-05-20	0.65	8	5	0.72	26	18	0.6	59	35	0.91	5	5	1.13	41	46	0.74	35	26
07-05-20	0.63	7	5	0.69	24	17	0.54	52	28	1.09	5	5	0.72	43	31	0.72	34	25
08-05-20	0.61	6	4	0.66	23	15	0.47	47	22	1.18	5	6	0.61	41	25	0.71	28	20
09-05-20	0.59	6	3	0.64	20	12	0.41	42	17	1.55	5	7	0.53	41	22	0.65	26	17
10-05-20	0.59	5	3	0.62	17	10	0.33	37	13	1.67	5	8	0.57	41	23	0.62	26	16
11-05-20	0.62	5	3	0.57	16	9	0.28	28	8	1.75	5	8	0.74	37	28	0.62	24	15
12-05-20	0.65	4	3	0.58	15	9	0.25	26	7	1.87	5	8	0.85	33	28	0.64	22	14
13-05-20	0.68	4	3	0.6	14	9	0.31	23	7	1.96	3	6	0.91	31	28	0.64	20	13
14-05-20	0.74	4	3	0.67	14	9	0.49	19	9	1.81	3	6	1.02	30	31	0.66	18	12
15-05-20	0.79	4	3	0.73	12	9	0.64	17	11	1.46	3	5	1.18	31	37	0.66	16	11
16-05-20	0.82	3	3	0.84	10	9	0.8	14	11	1.1	3	3	1.3	29	38	0.69	14	10
17-05-20	0.82	3	2	0.94	10	10	1.07	8	9	1	3	3	1.28	25	32	0.68	13	9
18-05-20	0.8	3	2	1.04	10	10	1.3	9	11	0.95	3	3	1.08	25	27	0.67	12	8
19-05-20	0.78	3	2	1.05	9	9	1.49	9	13	0.89	3	3	0.95	25	24	0.68	12	8
20-05-20	0.77	3	2	1.02	9	9	1.68	8	14	0.84	3	2	0.87	23	20	0.73	11	8
21-05-20	0.76	3	2	0.97	8	8	1.74	9	15	0.7	3	2	0.71	21	15	0.77	10	8
22-05-20	0.77	2	2	0.95	8	8	1.74	10	17	0.7	3	2	0.51	21	10	0.77	9	7
23-05-20	0.73	2	2	0.89	8	7	1.69	10	16	0.84	3	2	0.44	20	9	0.73	8	6
24-05-20	0.67	2	1	0.83	8	6	1.51	10	15	0.82	2	2	0.46	17	8	0.7	7	5
25-05-20	0.59	2	1	0.76	8	6	1.32	10	13	0.83	2	2	0.56	17	9	0.67	7	5
26-05-20	0.54	2	1	0.73	7	5	1.17	10	12	0.77	1	1	0.81	17	14	0.63	7	4

Successful identification of super-spreader



KEY IDEAS

- ✓ Risk evaluation often requires a short-term predictive model.
- ✓ Risk evaluation requires the proper assessment of the global picture of the situation with the elaboration of estimations that must be validated by surveys.
- ✓ Risk evaluation needs the development of more local or case-specific analysis that need to be set in the proper general perspective.

Thanks for your (virtual) attention!

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