

Supplementary materials for “Estimating the impact of physical distancing measures in containing COVID-19: an empirical analysis”

Table S1. Physical distancing measures

Physical distancing measure	No. of countries with measures	Average date of implementation	Average days after 1 st case	Average days after 100 th case
Restrictions on international travel	167	February 22, 2020	-10.8	-33.4
Cancel public events	165	March 11, 2020	8.3	-14.6
School closures	167	March 12, 2020	9.3	-13.5
Restrictions on size of gatherings	157	March 17, 2020	13.8	-9.1
Workplace closures	155	March 17, 2020	14.9	-7.6
Restrictions on internal movement	155	March 19, 2020	16.6	-6.2
Stay-at-home orders	152	March 22, 2020	18.5	-5.0
Public transport closures	130	March 22, 2020	18.5	-4.0

Author’s calculations based on the Oxford COVID-19 Government Response Tracker (OxCGRT). Data of 170 countries as of May 28, 2020.

Table S2. Pairwise correlation of physical distancing measures

	I	II	III	IV	V	VI	VII	VIII
I. School closure	1							
II. Workplace closure	0.552	1						
III. Cancel public events	0.711	0.474	1					
IV. Size restriction on gathering	0.534	0.489	0.617	1				
V. Public transport closure	0.404	0.534	0.408	0.450	1			
VI. Stay-at-home order	0.445	0.635	0.437	0.548	0.604	1		
VII. Internal movement restriction	0.502	0.575	0.533	0.592	0.631	0.689	1	
VIII. International travel restriction	0.475	0.342	0.502	0.464	0.450	0.432	0.512	1

Author’s calculations based on the Oxford COVID-19 Government Response Tracker (OxCGRT). Data of 170 countries as of May 28, 2020.

Table S3. Estimated impact of the type of physical distancing measures on COVID-19 transmission

	(1)	(2)	(3)	(4)
Restrictions on international travel				
1	-0.2287 (0.2299)			-0.3312 (0.2209)
2	-0.4322 (0.5014)			-0.5259 (0.4968)
3	0.3088 (0.2759)			0.3184 (0.2813)
4	-0.3192 (0.2371)			-0.2829 (0.2319)
5	-0.1270 (0.182)			-0.0403 (0.1795)
6	-0.2306 (0.1636)			-0.1872 (0.1674)
7	-0.4069** (0.1618)			-0.2500 (0.1731)
8	-0.5393*** (0.1691)			-0.3815** (0.1775)
Restrictions on mass gatherings				
1		-0.1673 (0.2002)		-0.0474 (0.2043)
2		N/A		N/A
3		-0.0738 (0.1477)		0.1158 (0.1810)
4		-0.3960** (0.1621)		-0.0997 (0.1902)
5		-0.1712 (0.1906)		0.0713 (0.2198)
6		-0.5214*** (0.1497)		-0.1476 (0.2027)
Lockdown				
1			0.0769 (0.1522)	-0.1082 (0.1742)
2			-0.5917** (0.2432)	-0.8266*** (0.2590)
3			-0.1475 (0.1805)	-0.2515 (0.1918)
4			-0.5442** (0.2190)	-0.4082* (0.2363)
5			-0.1845 (0.1328)	-0.1395 (0.1671)

6			-0.4961*** (0.1166)	-0.3690** (0.1591)
In GDP per capita	-0.0231 (0.0396)	-0.0411 (0.041)	-0.0477 (0.0404)	-0.0647 (0.0424)
In population density	-0.0225 (0.0315)	-0.0207 (0.0308)	-0.0091 (0.0296)	-0.0089 (0.0311)
% age 65 in population	-0.0028 (0.0105)	0.0033 (0.0102)	0.0062 (0.0100)	0.0030 (0.0101)
Temperature	-0.0210*** (0.0059)	-0.0197*** (0.0054)	-0.0173*** (0.0053)	-0.0170*** (0.0057)
Constant	2.6568*** (0.3766)	2.7066*** (0.3933)	2.6327*** (0.3739)	3.0237*** (0.4297)
Number of countries	142	142	142	142
R ²	0.334	0.334	0.375	0.470
Adjusted R ²	0.272	0.289	0.327	0.366

The dependent variable is the average R_t over the 7 days since the date of the 100th case. R_t , the time-varying reproduction number, is the expected number of secondary cases generated by a primary case at time t . The physical distancing measures are those that are in place on the date of the 100th case; refer to Table 1 for the specific measures. Standard errors are in parenthesis. ***, **, and * represents statistical significance at the 1%, 5%, and 10% level respectively. N/A denotes not available.

Table S4. Estimated impact of the type of physical distancing measures on growth of COVID-19 cases

	(1)	(2)	(3)	(4)
Restrictions on international travel				
1	-11.5241* (6.4055)			-13.9037** (6.3857)
2	-4.3420 (13.9714)			-6.8805 (14.3637)
3	-3.1768 (7.6889)			-1.5921 (8.1343)
4	-11.5567* (6.6056)			-9.7012 (6.7039)
5	-6.7669 (5.0718)			-4.3670 (5.1914)
6	-8.9413* (4.5579)			-6.2495 (4.8393)
7	-14.9550** (4.5095)			-9.4285* (5.0047)
8	-15.3598** (4.7113)			-9.8495* (5.1321)
Restrictions on mass gatherings				
1		-11.3489** (5.5239)		-8.0236 (5.9083)
2		N/A		N/A
3		-6.4666 (4.0747)		-0.1768 (5.2319)
4		-14.0559*** (4.4727)		-6.2775 (5.4983)
5		-10.5430** (5.2583)		-2.8170 (6.3564)
6		-15.9865*** (4.1313)		-5.9179 (5.8615)
Lockdown				
1			-3.0011 (4.2961)	-6.9561 (5.0370)
2			-10.9708 (6.8614)	-14.9819** (7.4892)
3			0.2952 (5.0943)	-2.7972 (5.5463)
4			-16.5760*** (6.1800)	-11.5052* (6.8333)
5			-8.4072** (3.7467)	-7.0555 (4.8320)

6			-12.7560*** (3.2912)	-10.0471** (4.5988)
In GDP per capita	0.2485 (1.1024)	-0.0591 (1.1325)	-0.4026 (1.1398)	-0.8913 (1.2256)
In population density	0.0542 (0.8772)	0.2200 (0.8492)	0.1598 (0.8366)	0.3009 (0.9004)
% age 65 in population	-0.0689 (0.2924)	0.0031 (0.2811)	0.0784 (0.2826)	0.0468 (0.2917)
Temperature	-0.4738*** (0.1651)	-0.4930*** (0.1483)	-0.4551*** (0.1503)	-0.3903** (0.1643)
Constant	27.4590*** (10.4931)	29.1527** (10.8533)	27.9928** (10.5507)	41.3448*** (12.4237)
Number of countries	142	142	142	142
R ²	0.310	0.323	0.335	0.408
Adjusted R ²	0.245	0.277	0.284	0.293

The dependent variable is the percent increase in total cases over the 14 days since the date of the 100th case. The physical distancing measures are those that are in place on the date of the 100th case; refer to Table 1 for the specific measures. Standard errors are in parenthesis. ***, **, and * represents statistical significance at the 1%, 5%, and 10% level respectively. N/A denotes not available.

Table S5. Predicted time-varying reproduction numbers on date of the 100th case

Country	SI	TR	MG	LD	Predicted R_t	Estimated R_t using reported data	Difference	Total cases as of May 28, 2020
Madagascar	95.37	7	4	6	1.34	0.74	-0.60	612
Japan	25.00	6	1	0	1.87	1.27	-0.59	16,651
Myanmar	86.11	6	6	6	1.31	0.74	-0.56	206
Finland	42.59	6	3	1	1.93	1.41	-0.52	6,692
Brunei	52.78	8	4	0	1.25	0.73	-0.52	141
Ethiopia	73.15	4	6	6	1.30	0.83	-0.47	731
Egypt	18.52	0	0	3	1.80	1.33	-0.47	19,666
Iceland	16.67	4	0	0	1.98	1.53	-0.45	1,805
Kuwait	74.07	7	5	3	1.33	0.89	-0.44	23,267
Thailand	33.80	3	3	0	1.89	1.45	-0.44	3,054
Vietnam	50.00	8	3	5	1.51	1.10	-0.41	327
Guam	67.59	5	6	6	1.09	0.68	-0.41	171
Greece	40.74	0	3	3	1.82	1.41	-0.40	2,903
Sweden	0.00	0	0	0	2.15	1.75	-0.40	35,088
Bahrain	25.00	1	0	0	1.47	1.10	-0.37	9,633
Eswatini	82.41	8	4	5	1.40	1.04	-0.36	272
Slovenia	28.70	5	4	1	1.68	1.32	-0.36	1,471
Liberia	79.63	6	6	6	1.33	0.97	-0.36	266
Iraq	77.78	5	6	5	1.58	1.22	-0.36	5,135
Aruba	82.41	6	6	6	1.09	0.74	-0.35	101
Norway	11.11	0	0	0	2.13	1.79	-0.34	8,383
Rwanda	100.00	8	6	6	1.25	0.92	-0.33	346
Senegal	66.67	7	6	5	1.37	1.06	-0.32	3,253
Estonia	44.44	1	3	5	1.76	1.44	-0.32	1,840
Jordan	100.00	7	5	6	1.39	1.09	-0.30	720
Trinidad and Tobago	79.63	8	6	6	0.96	0.67	-0.29	116
Andorra	31.48	0	1	6	1.51	1.25	-0.26	763
Kosovo	92.59	7	6	6	1.42	1.17	-0.25	1,047
Bermuda	96.30	8	6	6	0.95	0.71	-0.25	139
Algeria	36.11	5	3	0	1.86	1.62	-0.24	8,857
Tanzania	46.30	8	4	0	1.52	1.29	-0.24	509
Taiwan	27.78	8	1	0	1.45	1.21	-0.24	441
Bulgaria	70.37	6	6	6	1.49	1.26	-0.23	2,460
Russia	60.65	6	4	5	2.01	1.82	-0.19	370,680
Venezuela	82.41	7	4	6	1.09	0.90	-0.18	1,245
Cuba	66.67	6	3	5	1.61	1.43	-0.18	1,974
Uruguay	54.63	5	3	2	1.35	1.18	-0.16	803
Mozambique	50.93	4	4	1	1.57	1.41	-0.16	227
Slovak Republic	75.00	7	4	4	1.36	1.21	-0.16	1,515
Ghana	52.78	8	4	0	1.36	1.23	-0.13	7,303
Burkina Faso	84.26	7	3	6	1.36	1.23	-0.13	845
Afghanistan	62.04	1	3	6	1.55	1.42	-0.13	12,456
Democratic Republic of Congo	77.78	8	4	6	1.22	1.09	-0.13	2,659
Kyrgyz Republic	92.13	8	6	6	1.46	1.33	-0.13	1,594
Mauritius	82.41	7	3	6	1.30	1.18	-0.12	334
Azerbaijan	68.52	6	6	5	1.67	1.56	-0.12	4,568
Hong Kong	45.37	6	3	2	1.23	1.11	-0.11	1,066
Albania	84.26	7	4	6	1.43	1.32	-0.10	1,050
San Marino	83.33	7	6	4	1.18	1.08	-0.10	667
Bosnia and Herzegovina	89.81	5	6	6	1.54	1.44	-0.10	2,435
Denmark	35.19	3	3	1	2.01	1.92	-0.10	11,480

Tunisia	87.96	5	5	6	1.51	1.41	-0.10	1,051
Georgia	100.00	8	6	6	1.35	1.26	-0.09	735
Pakistan	52.78	6	5	0	1.85	1.76	-0.09	61,227
Niger	61.11	7	4	5	1.45	1.36	-0.09	955
Cape Verde	75.93	8	3	6	1.32	1.24	-0.09	390
Uzbekistan	90.74	7	3	6	1.60	1.52	-0.09	3,333
Lebanon	52.78	8	1	4	1.21	1.13	-0.08	1,161
Qatar	30.56	6	1	0	1.44	1.38	-0.07	48,947
Guyana	90.74	8	6	6	1.07	1.01	-0.07	139
Kazakhstan	80.09	7	6	5	1.62	1.56	-0.06	9,576
Indonesia	43.52	6	3	1	1.59	1.53	-0.06	23,851
India	48.15	6	3	1	1.65	1.60	-0.05	158,333
Argentina	88.89	7	5	5	1.59	1.54	-0.05	13,920
Paraguay	93.52	7	6	6	1.18	1.13	-0.05	884
Kenya	83.33	8	6	6	1.11	1.06	-0.05	1,471
Sri Lanka	97.22	8	6	6	1.03	0.99	-0.04	1,469
Philippines	75.00	6	3	5	1.63	1.60	-0.03	15,049
Bolivia	96.30	7	6	6	1.27	1.24	-0.03	7,768
Canada	22.22	2	3	0	2.02	2.02	0.00	87,508
Costa Rica	71.30	7	3	6	1.29	1.30	0.01	984
Czech Republic	57.41	6	3	3	1.81	1.82	0.01	9,086
United Kingdom	11.11	0	0	0	2.04	2.05	0.01	267,240
Chile	47.22	0	3	5	1.86	1.87	0.01	82,289
Congo	97.22	8	4	6	1.12	1.13	0.01	571
Mexico	2.78	1	0	0	1.62	1.63	0.02	78,023
United Arab Emirates	45.37	6	3	2	1.15	1.17	0.03	31,969
Peru	94.44	7	5	5	1.55	1.57	0.03	135,905
Austria	19.44	5	0	0	2.02	2.05	0.03	16,515
Puerto Rico	93.52	6	6	6	1.15	1.18	0.03	3,397
Poland	57.41	7	3	3	1.76	1.81	0.04	22,473
Cyprus	92.59	7	5	6	1.30	1.35	0.04	939
Honduras	100.00	7	6	6	1.21	1.26	0.04	4,640
El Salvador	88.89	8	4	6	1.07	1.12	0.05	2,109
Mali	72.22	5	4	6	1.27	1.32	0.06	1,116
Somalia	56.48	8	4	1	1.38	1.44	0.06	1,731
Ireland	48.15	0	5	1	1.73	1.79	0.06	24,803
Netherlands	2.78	0	0	1	1.88	1.95	0.06	45,768
Serbia	81.48	8	6	5	1.55	1.62	0.07	11,275
Singapore	25.00	6	1	0	1.38	1.45	0.07	32,876
South Africa	55.56	6	3	1	1.64	1.71	0.07	25,937
Romania	61.11	6	4	3	1.65	1.73	0.08	18,594
Sierra Leone	80.56	8	4	6	1.17	1.26	0.09	782
Guatemala	93.52	6	6	6	1.22	1.31	0.09	4,145
Lithuania	81.48	7	6	6	1.45	1.55	0.10	1,647
Nigeria	82.87	8	6	6	1.02	1.13	0.10	8,733
South Sudan	92.59	8	6	6	1.11	1.22	0.11	806
Malaysia	22.22	6	1	0	1.54	1.67	0.13	7,619
Switzerland	25.00	0	4	0	1.85	1.98	0.14	30,678
Saudi Arabia	68.52	7	3	5	1.51	1.66	0.14	78,541
Central African								
Republic	68.52	8	4	6	1.21	1.36	0.15	702
Hungary	67.59	7	4	4	1.34	1.49	0.15	3,816
Cote d'Ivoire	80.56	7	4	6	1.18	1.33	0.15	2,556
Moldova	87.04	7	6	6	1.44	1.60	0.16	7,537
Morocco	90.74	7	4	6	1.38	1.55	0.17	7,601
Panama	51.85	6	3	1	1.51	1.69	0.18	11,728
Cameroon	57.41	5	4	4	1.25	1.43	0.19	5,436
Uganda	87.04	6	4	6	1.39	1.58	0.19	281

Gabon	87.04	8	6	6	1.03	1.22	0.19	2,319
New Zealand	75.93	8	6	5	1.36	1.56	0.20	1,154
Belgium	13.89	1	0	0	1.76	1.97	0.21	57,592
Guinea	73.15	7	4	6	1.22	1.44	0.22	3,446
Croatia	66.67	8	5	6	1.40	1.63	0.23	2,244
Nepal	92.59	8	6	6	1.30	1.54	0.24	886
Luxembourg	79.63	0	6	6	1.44	1.68	0.25	4,001
Colombia	50.93	3	4	2	1.31	1.56	0.25	24,104
Australia	19.44	6	0	0	1.63	1.89	0.26	7,139
Belarus	8.33	5	0	0	2.06	2.32	0.26	38,956
Palestine	94.44	7	6	6	1.27	1.54	0.26	613
Brazil	42.13	3	3	1	1.77	2.06	0.29	411,821
Ukraine	88.89	7	6	6	1.48	1.77	0.29	21,584
Zambia	65.28	8	6	5	1.44	1.74	0.30	1,057
France	19.44	4	3	0	1.87	2.21	0.34	145,746
Ecuador	93.52	7	3	5	1.59	1.94	0.34	38,103
Chad	88.89	8	4	6	1.09	1.45	0.36	715
Benin	59.72	4	6	5	1.41	1.78	0.37	339
Portugal	32.41	5	0	3	1.77	2.14	0.37	31,292
Jamaica	78.70	4	6	6	1.18	1.55	0.37	569
South Korea	45.37	5	3	0	2.07	2.45	0.38	11,344
Oman	81.48	8	6	6	0.97	1.35	0.38	8,373
Spain	11.11	0	0	0	2.02	2.40	0.38	236,769
Dominican Republic	81.48	7	3	5	1.55	1.96	0.41	15,723
Israel	52.78	8	4	0	1.39	1.82	0.42	16,793
China	8.33	0	0	0	2.32	2.75	0.43	84,106
United States	11.11	5	1	0	1.83	2.28	0.45	1,699,933
Sudan	81.48	8	4	6	1.09	1.57	0.48	4,146
Djibouti	94.44	7	6	6	1.15	1.66	0.51	2,697
Iran	18.52	0	3	1	1.87	2.40	0.54	141,591
Germany	25.00	1	1	0	1.62	2.21	0.59	179,717
Italy	69.91	6	5	5	1.74	2.36	0.62	231,139
Turkey	58.33	6	3	3	1.78	2.59	0.81	158,762
Bangladesh	87.04	6	6	6	1.25	2.20	0.96	38,292

SI is the Stringency Index, a composite index of physical distancing measures with a range of 0 to 100, calculated by the Oxford COVID-19 Government Response Tracker (OxCGRT); a larger value indicates higher stringency. TR refers to restrictions on international travel, MG refers to restrictions on mass gatherings, and LD refers to lockdown (see Table 1 for the specific measures). Predicted R_t is the average predicted time-varying reproduction number over the two weeks following the date of the 100th case, using a regression model. Estimated R_t is the estimated time-varying reproduction number using reported case data, averaged over the two weeks following the date of the 100th case.

Figure S1. Schematic of methodology

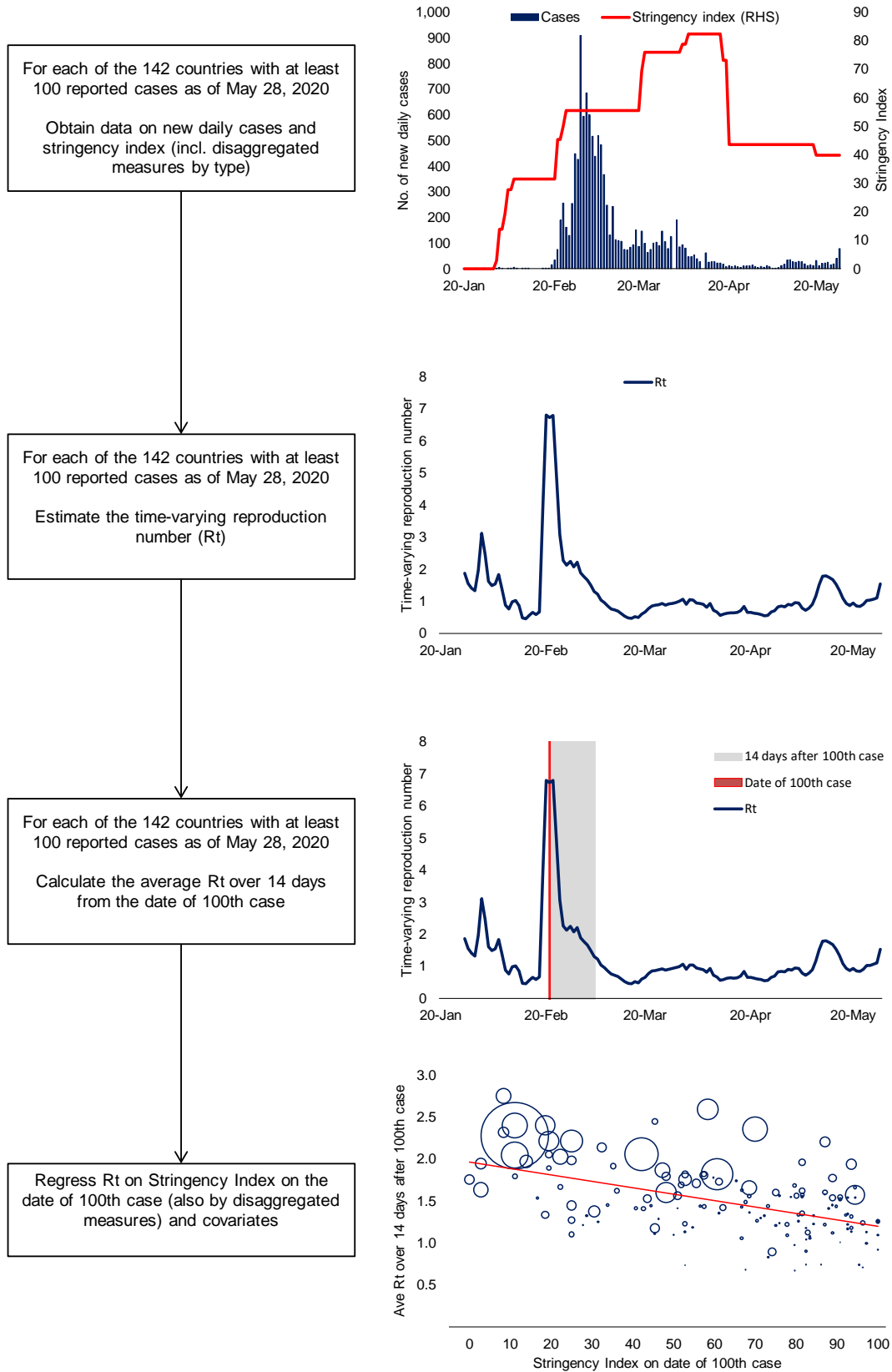
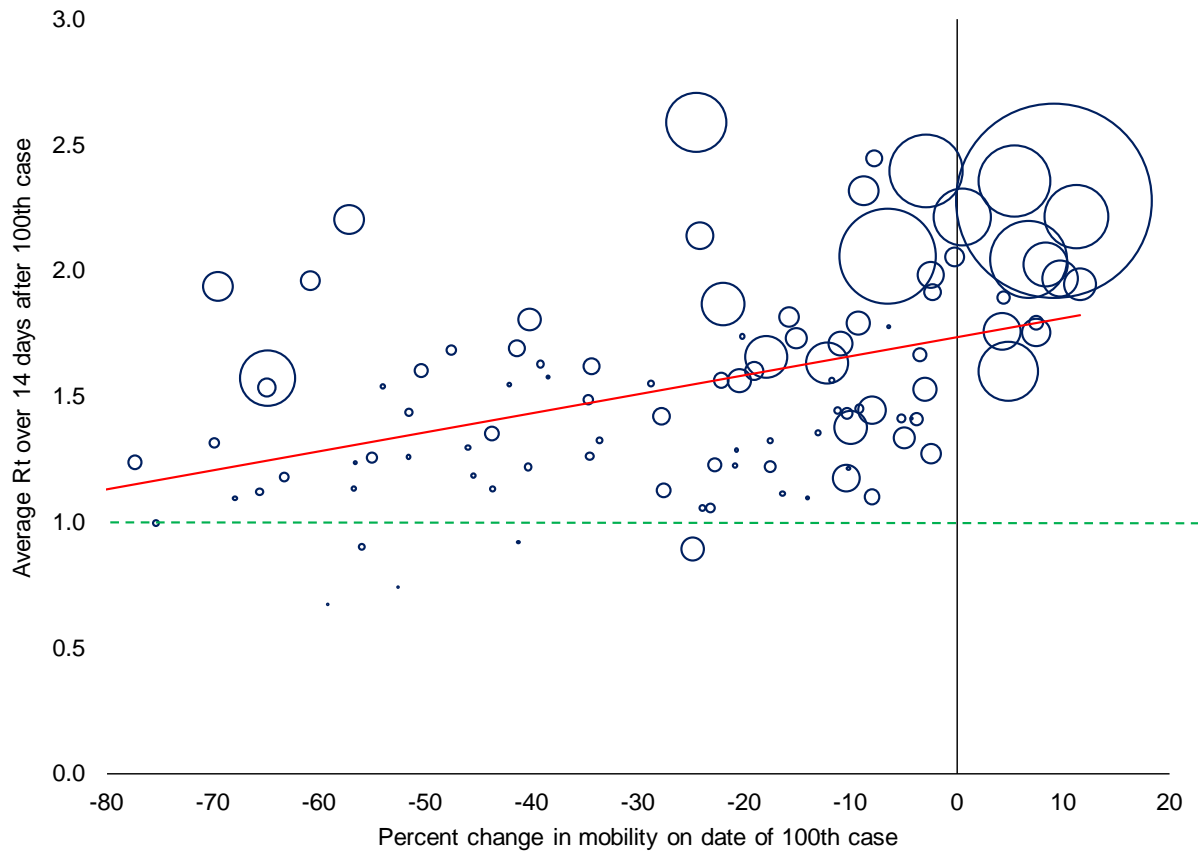


Figure S2. Percent change in mobility on the date of the 100th case and average reproduction numbers in the following two weeks



The time-varying reproduction number R_t is the expected number of secondary cases generated by a primary case at time t . The change in mobility (average of retail and recreation, grocery and pharmacy, parks, transit and workplaces) is relative to the baseline median value of the corresponding day of the week during January 3 to February 6, 2020; data for 103 countries from Google Community Mobility Trends Reports. Each bubble represents a country, and the size of the bubble is proportional to the total number of reported cases as of May 28, 2020. The red solid line is the best linear fit of the relationship between the stringency level on the date of the 100th reported case and the average R_t in the following two weeks. The green dashed line is the R_t threshold: a value below one indicates that a sustained outbreak is unlikely if the measures remain in place.