Supplementary materials

A Regression models of exponential growth

A.1 General equations

During the first part of the development of an epidemic, we can assume an exponential growth according to Equation 1

$$y = \alpha\beta^{\gamma x} = \alpha e^{(\gamma \log \beta)x} \tag{1}$$

where: $y =$ is the cumulative case count, $x =$ number of days since the start of the series

This equation can be linearized using logarithms, shown in Equation 2, and its equivalent Equation 3

$$\log y = \log \alpha + (\gamma \log \beta)x \tag{2}$$

$$\log y = A + Bx \tag{3}$$

where: $A = \log \alpha$, $B = \gamma \log \beta$

A.2 Model data selection

The MPX data obtained from the Global Health Data Science Initiative, was filtered using the following procedure:

1. Only cases with a confirmed status were kept
2. Data for which the confirmation date ranged from the epidemiological weeks 20 to 33 of 2022 were used. This allowed us to consider only cases in non-endemic countries
3. Data was combined by confirmation date at the country level, and, after ordering each country timeseries, a cumulative number of cases was calculated

4. Data from countries with 200 or more cumulative cases, up to the mos recent reported date, were considered for modeling
5. From the selected countries, we used only dates for which the number of cumulative cases was equal or greater than 10.
6. For each country timeseries, we created a days count series which reflected the difference between the earliest date in the series and the current one.

At the end of this selection procedure, we obtained the list in the following table:

Table 1: Countries selected for modeling

	Confirmation dates		
Country	Earliest	Latest	N° Obs.[1]
Austria	2022-06-17	2022-08-19	16
Belgium	2022-06-01	2022-08-15	14
Brazil	2022-06-22	2022-08-19	50
Canada	2022-05-23	2022-08-18	48
England	2022-05-20	2022-08-15	32
France	2022-05-28	2022-08-18	27
Germany	2022-05-24	2022-08-19	69
Italy	2022-05-26	2022-08-19	31
Mexico	2022-06-28	2022-08-15	10
Netherlands	2022-05-25	2022-08-18	24
Northern Ireland	2022-07-04	2022-08-15	9
Peru	2022-07-04	2022-08-18	33
Portugal	2022-05-18	2022-08-10	36
Scotland	2022-06-06	2022-08-15	21
Spain	2022-05-20	2022-08-16	37
Switzerland	2022-06-07	2022-08-16	48
United States	2022-05-26	2022-08-18	74
Wales	2022-06-30	2022-08-15	12

[1] Number of days with reports of confirmed cases in the date range

A.3 Regression results

Using Equation 3, we performed a regression of the logarithm (base 10) of the cumulative number of cases versus the days counts (*vide supra*)

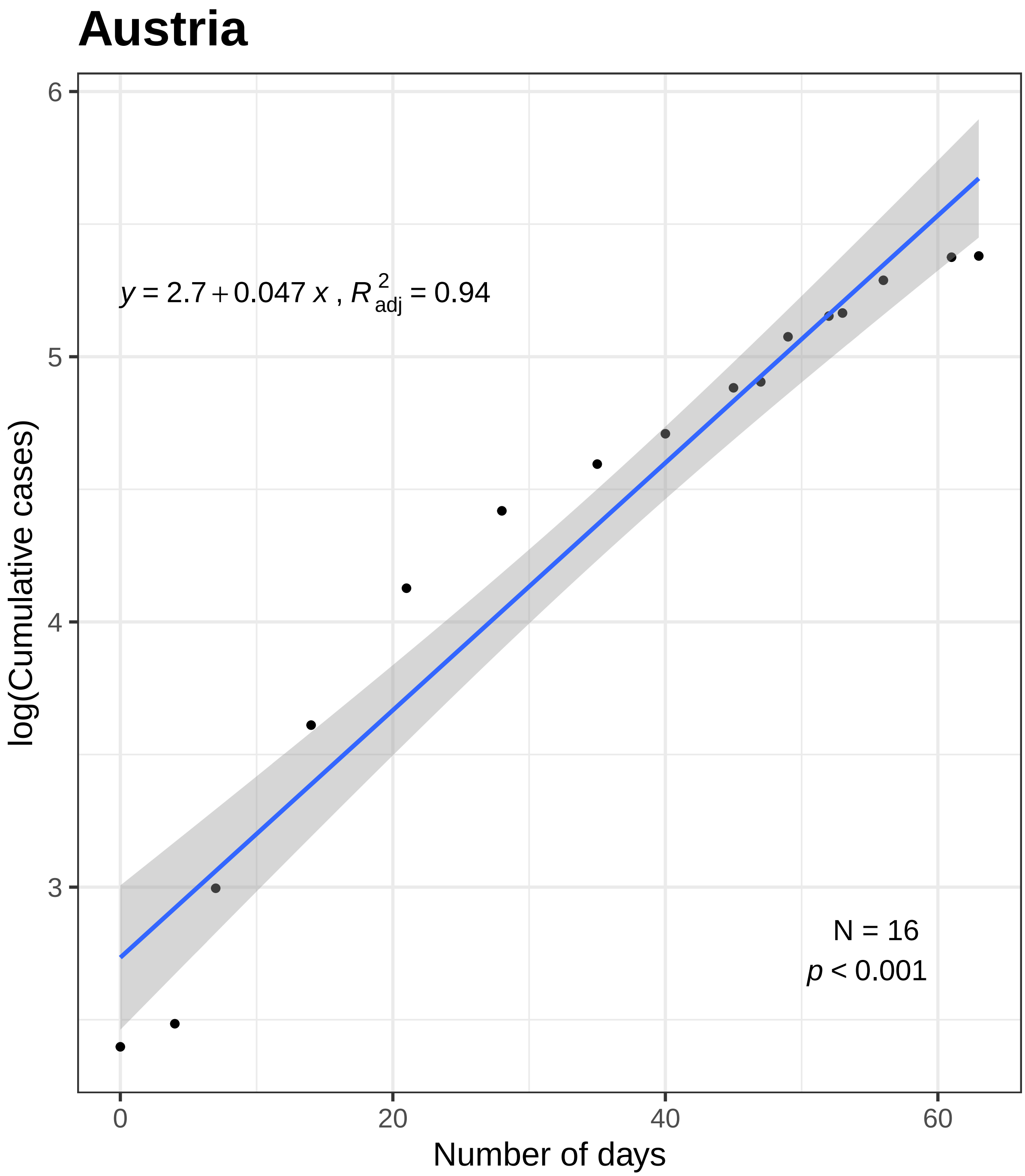
The results of the regressions can be seen in the following table

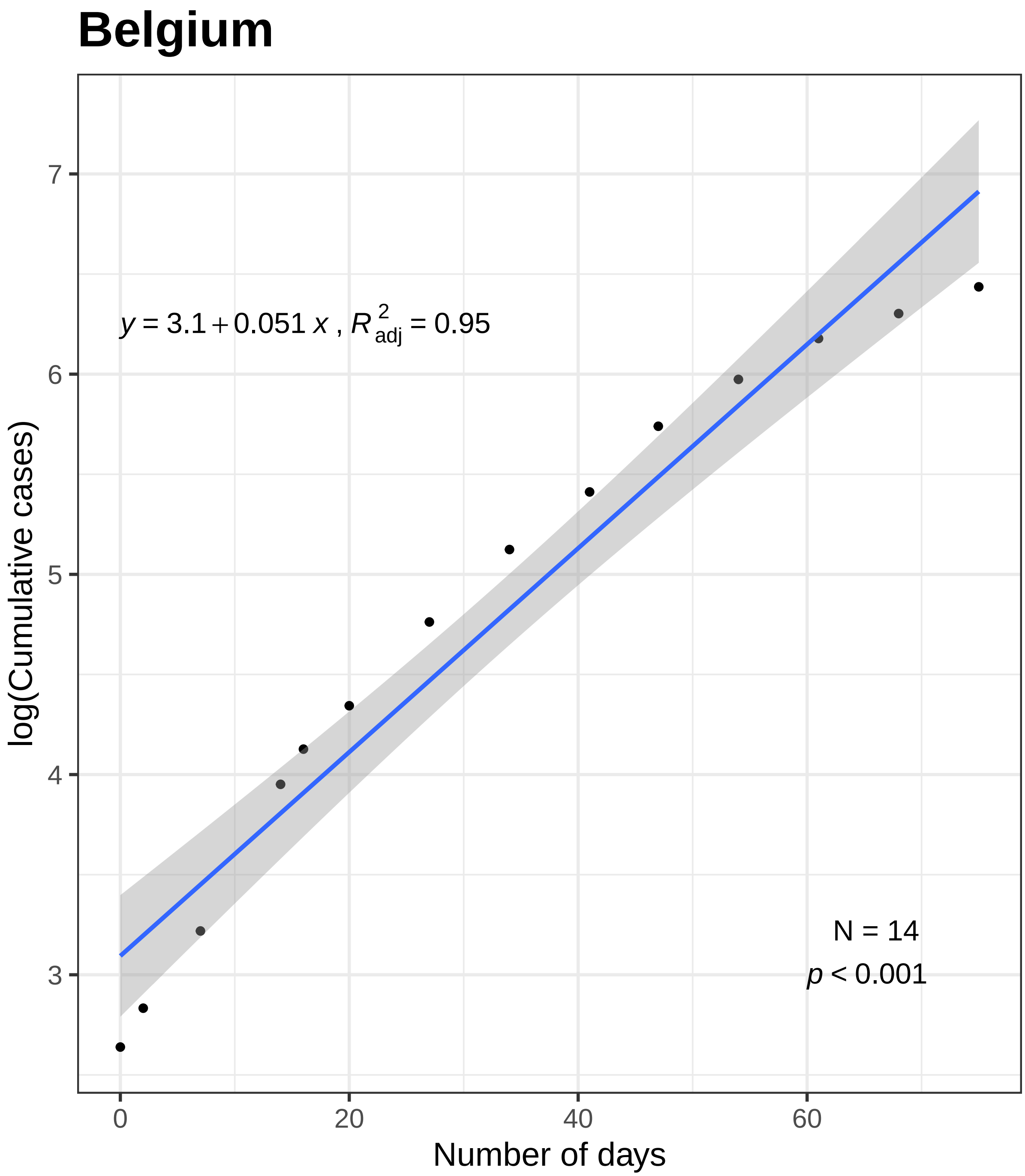
Table 2: Regression results for the selected countries

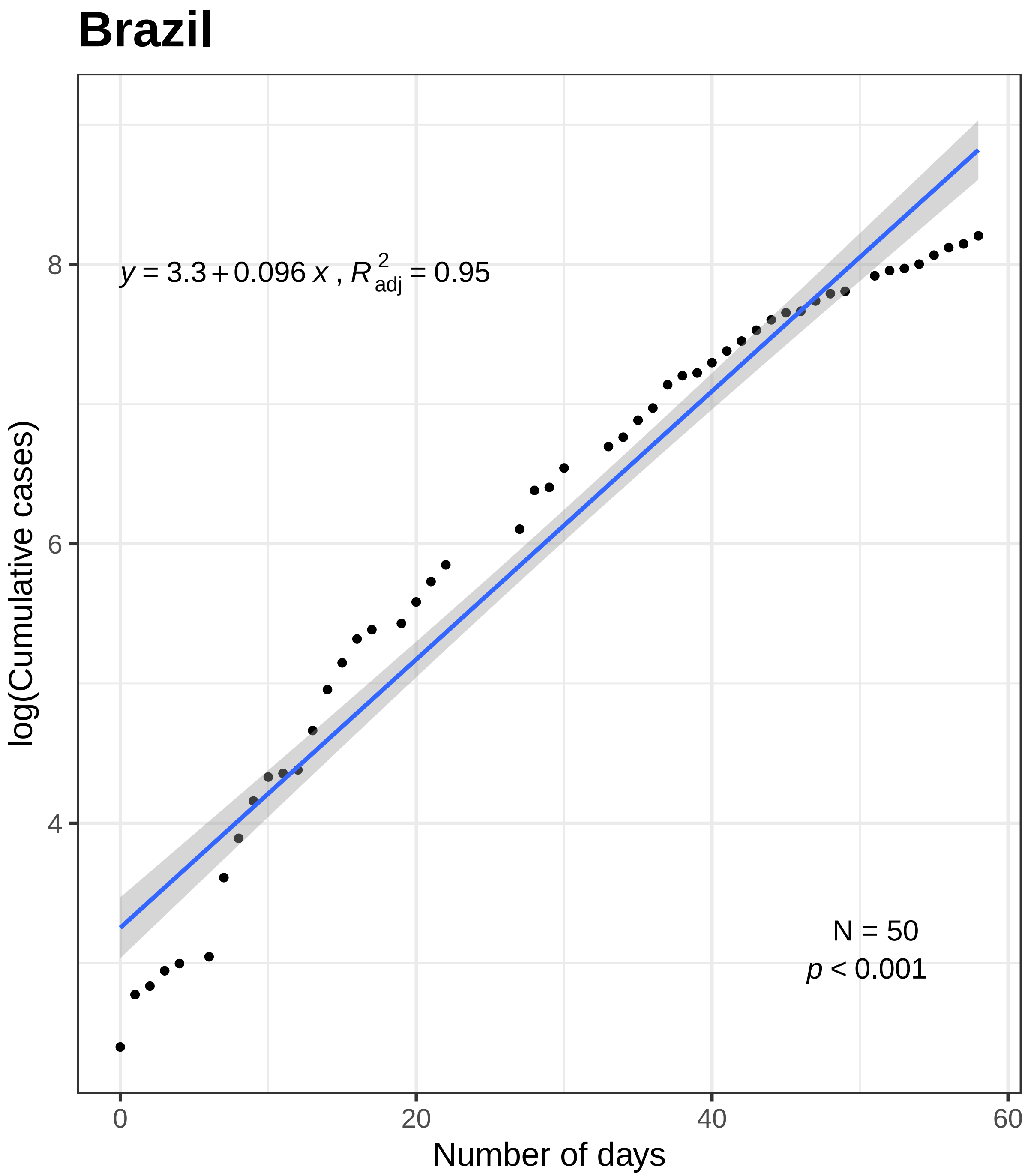
	Parameters				Statistics		
Country	Intercept	S.E.$_{inter.}$	Slope	S.E.$_{slope}$	R^2_{adj}	p-value	N° Obs.[1]
Austria	2.7343	0.1268	0.0466	0.0031	0.9387	< 0.001	16
Belgium	3.0941	0.1394	0.0509	0.0034	0.9451	< 0.001	14
Brazil	3.2519	0.1084	0.0960	0.0031	0.9501	< 0.001	50
Canada	3.8792	0.0945	0.0411	0.0018	0.9170	< 0.001	48
England	4.5412	0.1522	0.0498	0.0035	0.8668	< 0.001	32
France	3.7041	0.1572	0.0611	0.0035	0.9231	< 0.001	27
Germany	3.9707	0.1493	0.0589	0.0030	0.8500	< 0.001	69
Italy	2.9108	0.1089	0.0501	0.0024	0.9353	< 0.001	31
Mexico	2.6138	0.1198	0.0571	0.0042	0.9530	< 0.001	10
Netherlands	3.4176	0.1576	0.0508	0.0032	0.9181	< 0.001	24
Northern Ireland	2.3369	0.0621	0.0253	0.0026	0.9201	< 0.001	9
Peru	3.1798	0.0844	0.0878	0.0030	0.9650	< 0.001	33
Portugal	3.9802	0.1311	0.0419	0.0035	0.8011	< 0.001	36
Scotland	2.5533	0.0755	0.0300	0.0020	0.9192	< 0.001	21
Spain	4.1544	0.1020	0.0602	0.0023	0.9513	< 0.001	37
Switzerland	3.0812	0.0895	0.0482	0.0022	0.9091	< 0.001	48
United States	2.8221	0.0498	0.0868	0.0011	0.9892	< 0.001	74
Wales	2.5697	0.0579	0.0288	0.0023	0.9344	< 0.001	12

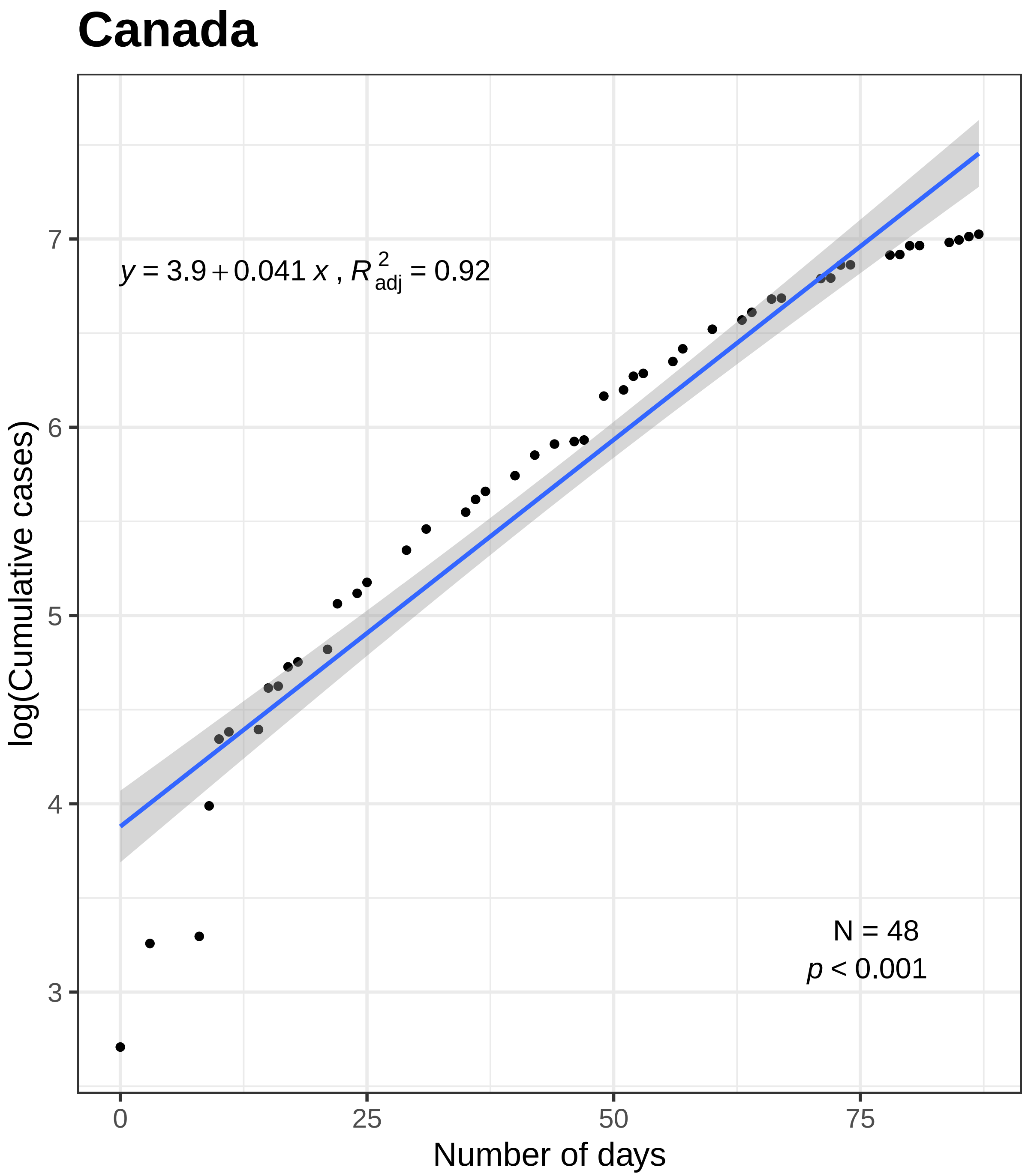
[1] Number of days with reports of confirmed cases in the date range

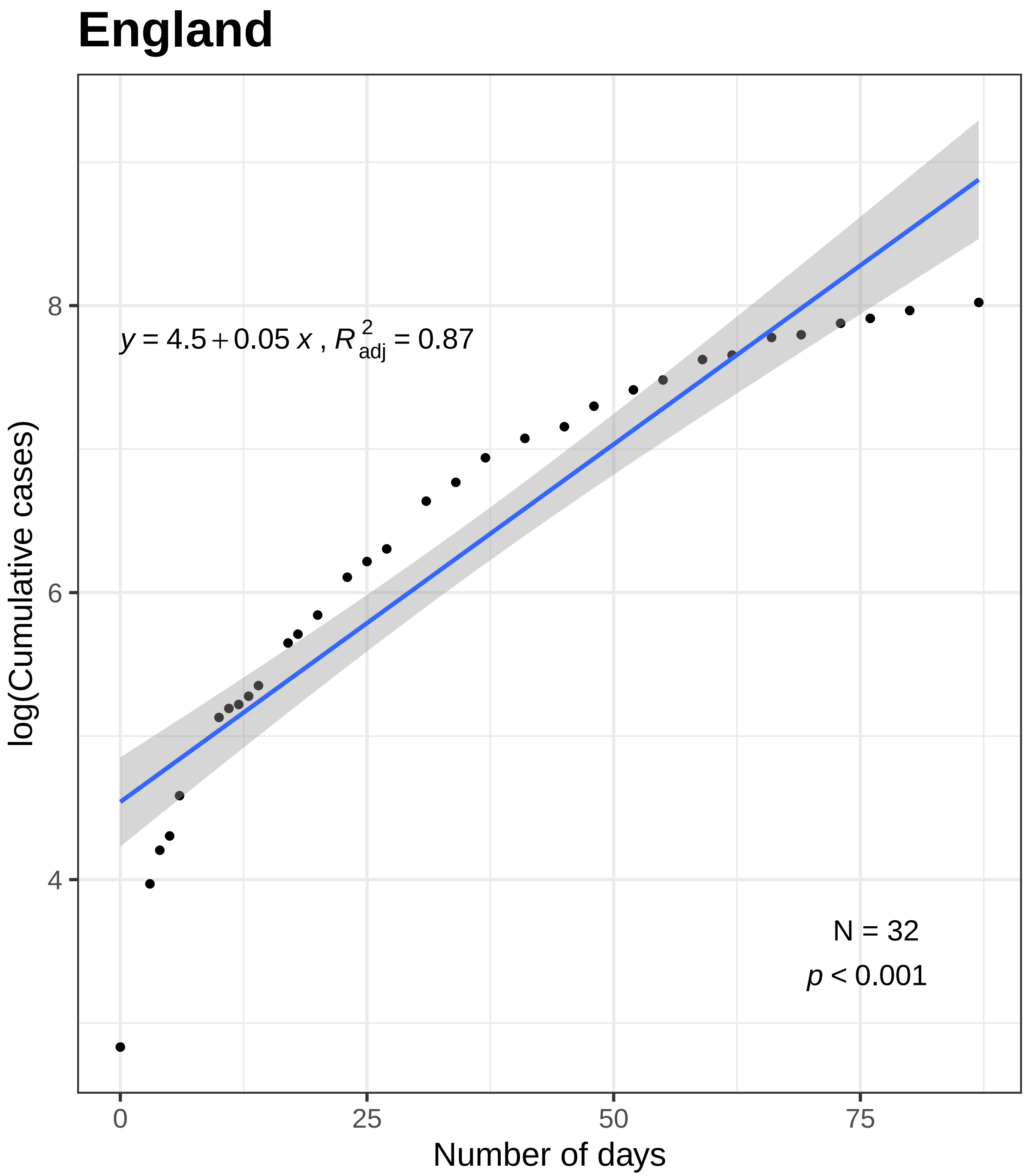
A.4 Plots of the regression results per country

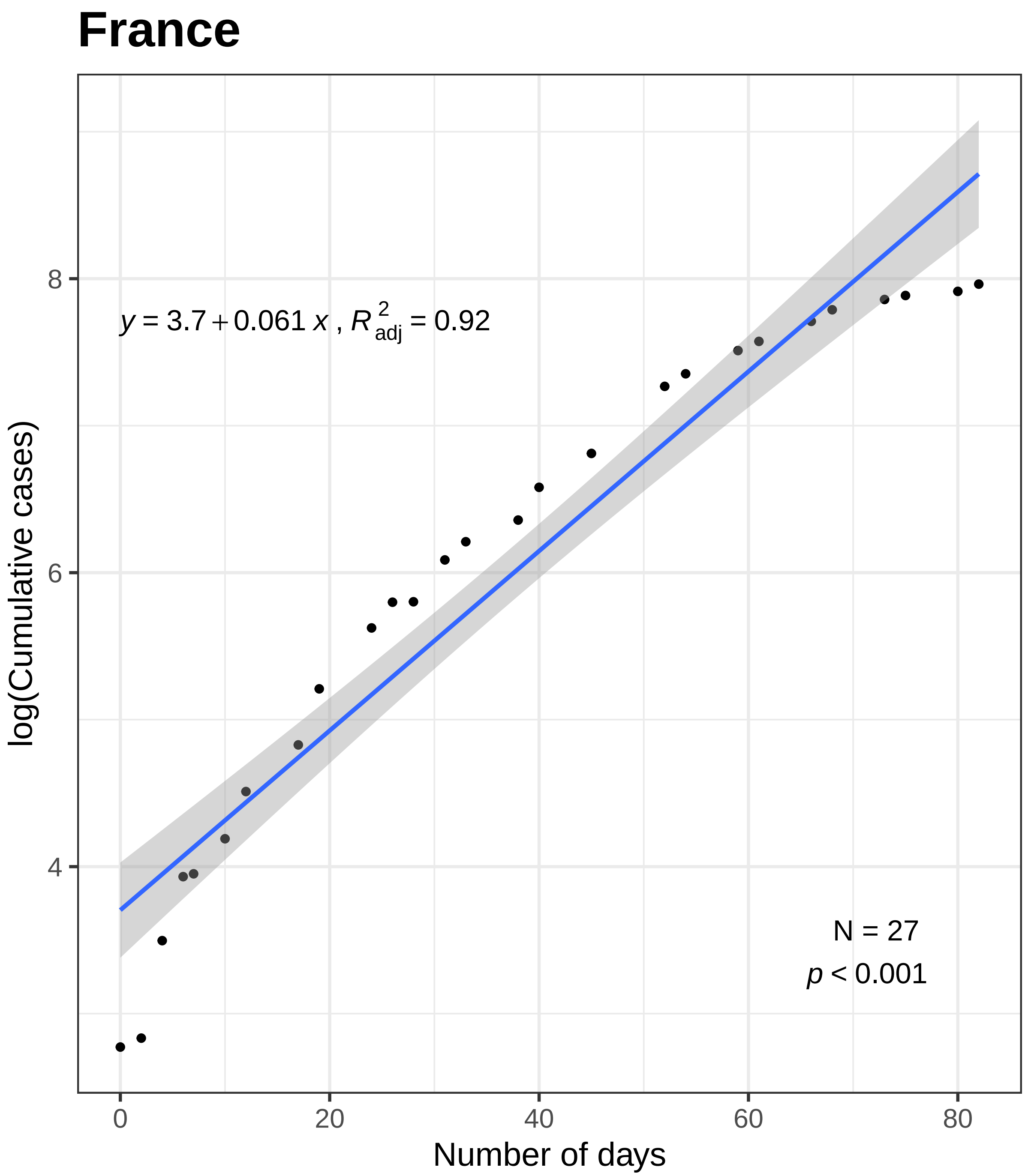



Belgium
$y = 3.1 + 0.051\,x,\ R^2_{adj} = 0.95$
N = 14
$p < 0.001$
log(Cumulative cases)
Number of days
7
6
5
4
3
0
20
40
60


Brazil
y = 3.3 + 0.096 x , R 2 adj = 0.95
N = 50
p < 0.001
log(Cumulative cases)
8
6
4
0
20
40
60
Number of days

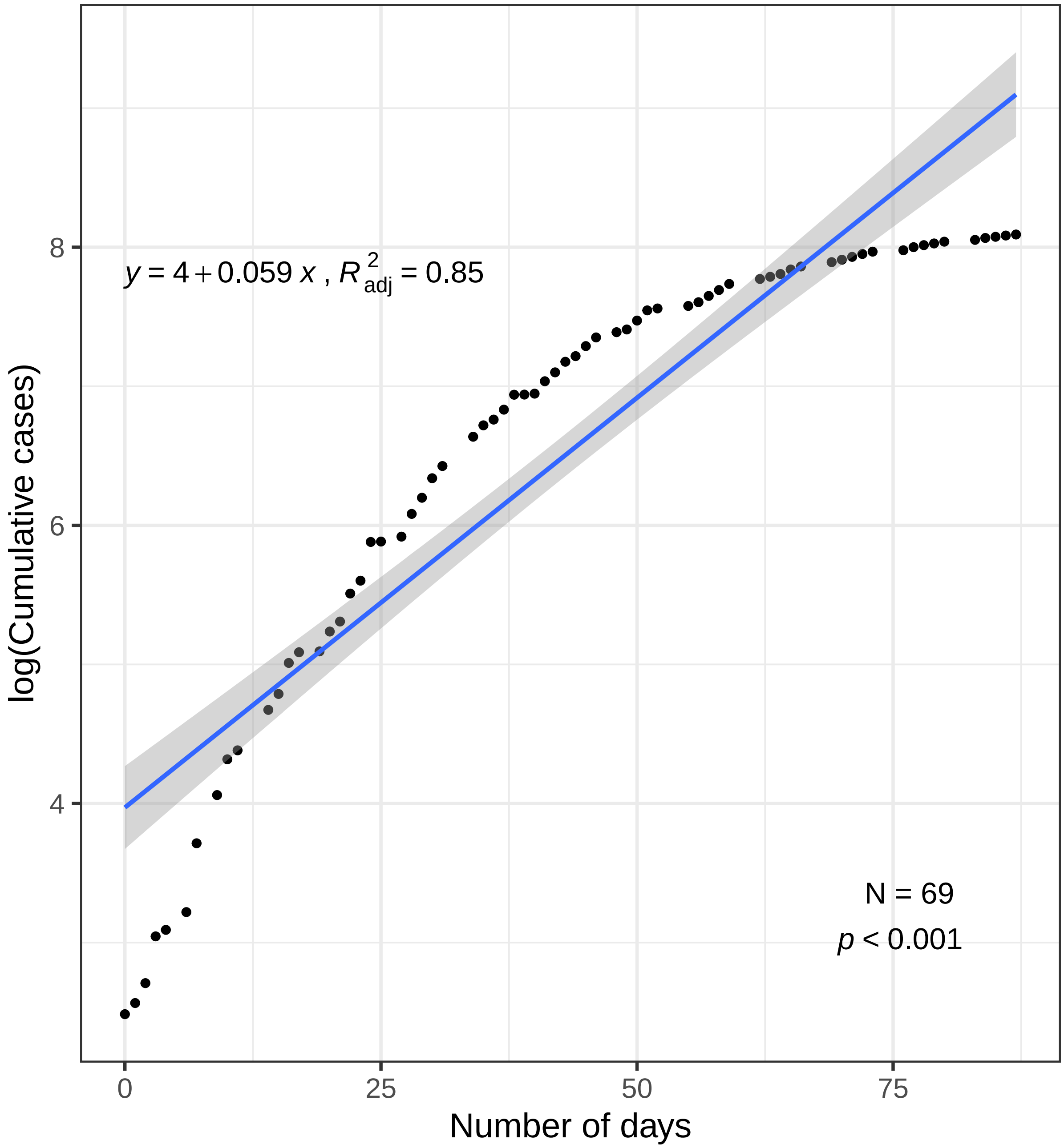

Canada
$y = 3.9 + 0.041\,x$, $R^2_{adj} = 0.92$
N = 48
$p < 0.001$
log(Cumulative cases)
Number of days
0
25
50
75
3
4
5
6
7


England
$y = 4.5 + 0.05\,x$, $R^2_{adj} = 0.87$
N = 32
$p < 0.001$
log(Cumulative cases)
Number of days
8
6
4
0
25
50
75

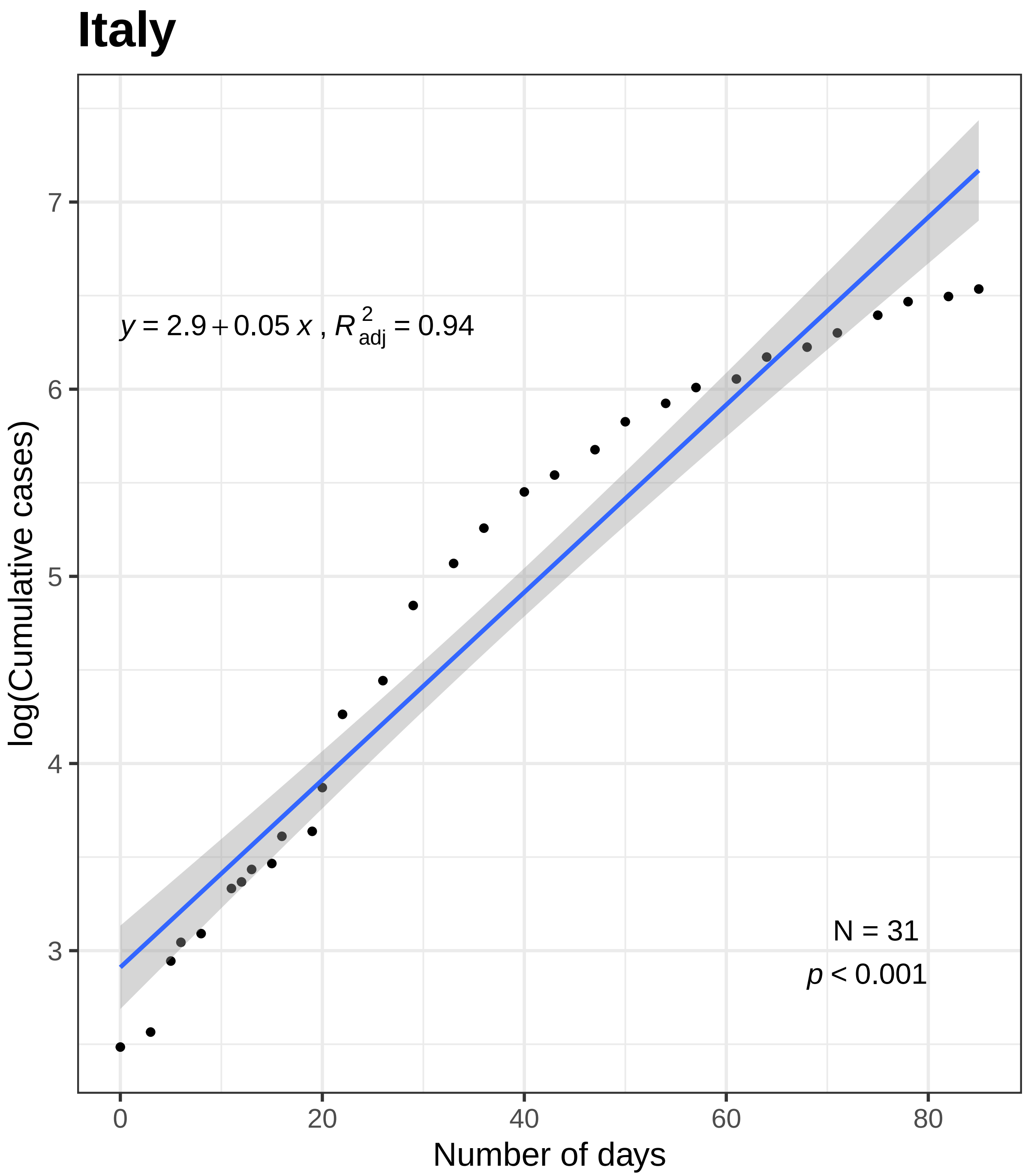


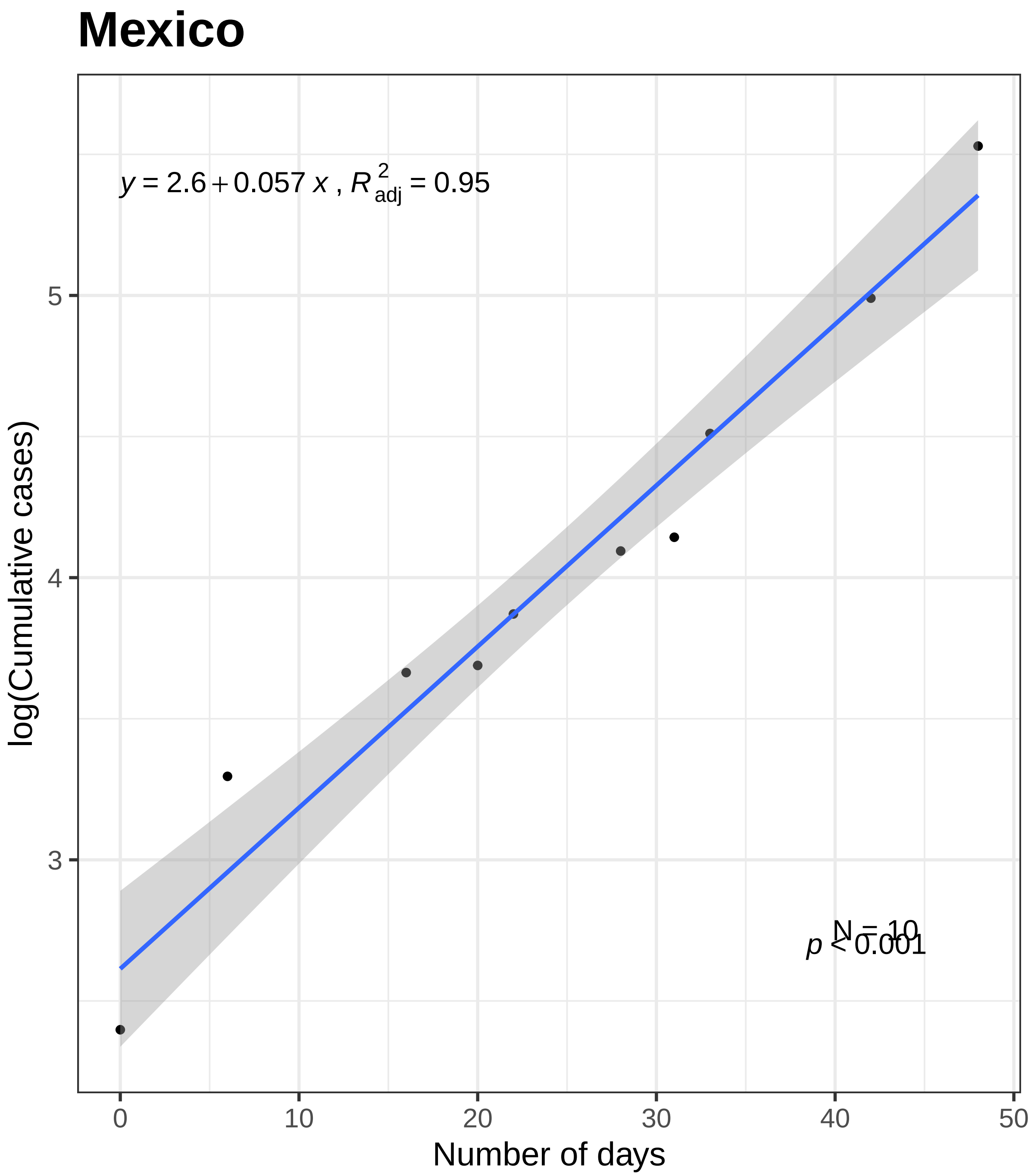
France
$y = 3.7 + 0.061\,x$, $R^2_{adj} = 0.92$
N = 27
$p < 0.001$
log(Cumulative cases)
8
6
4
0
20
40
60
80
Number of days

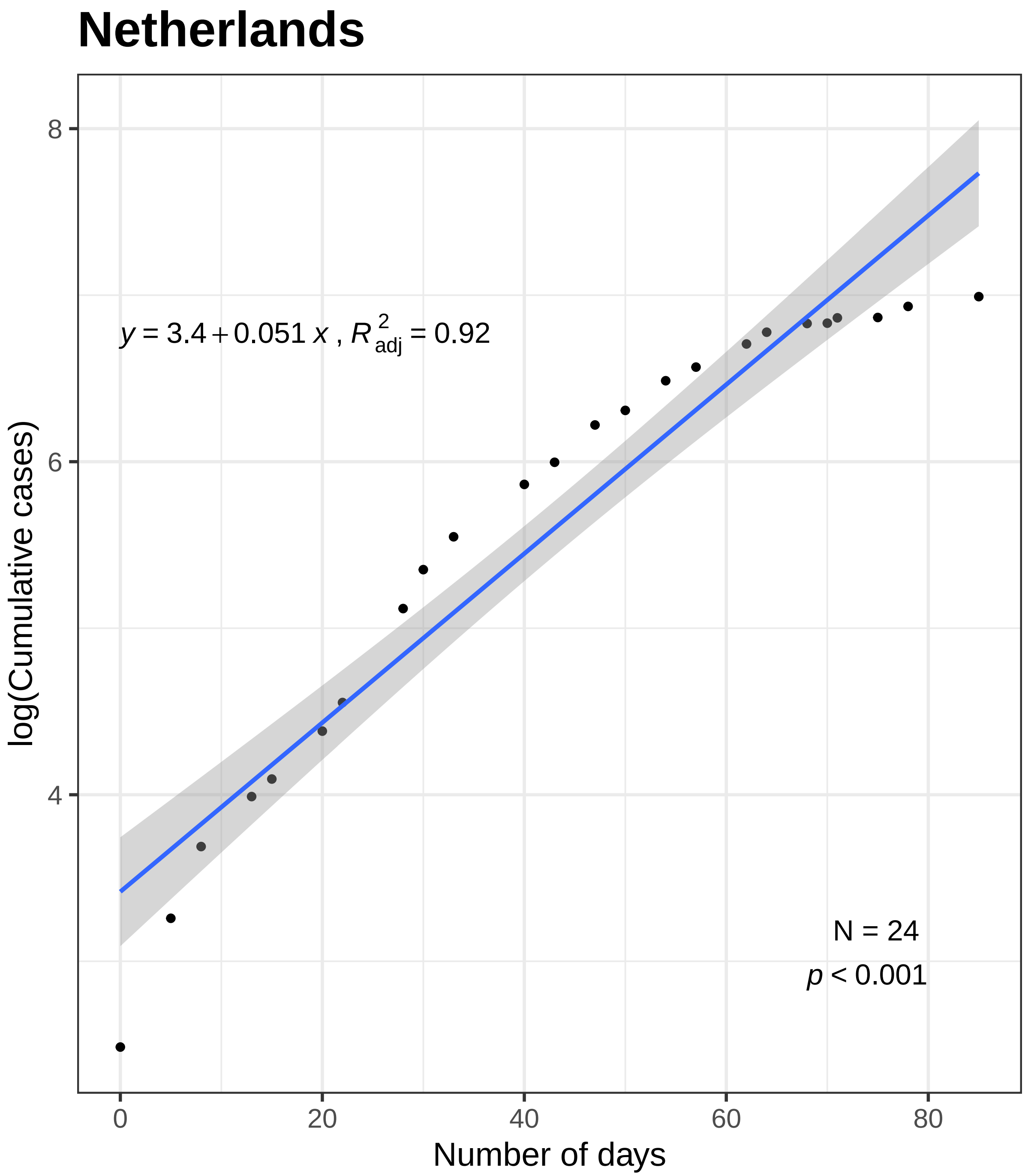
Germany

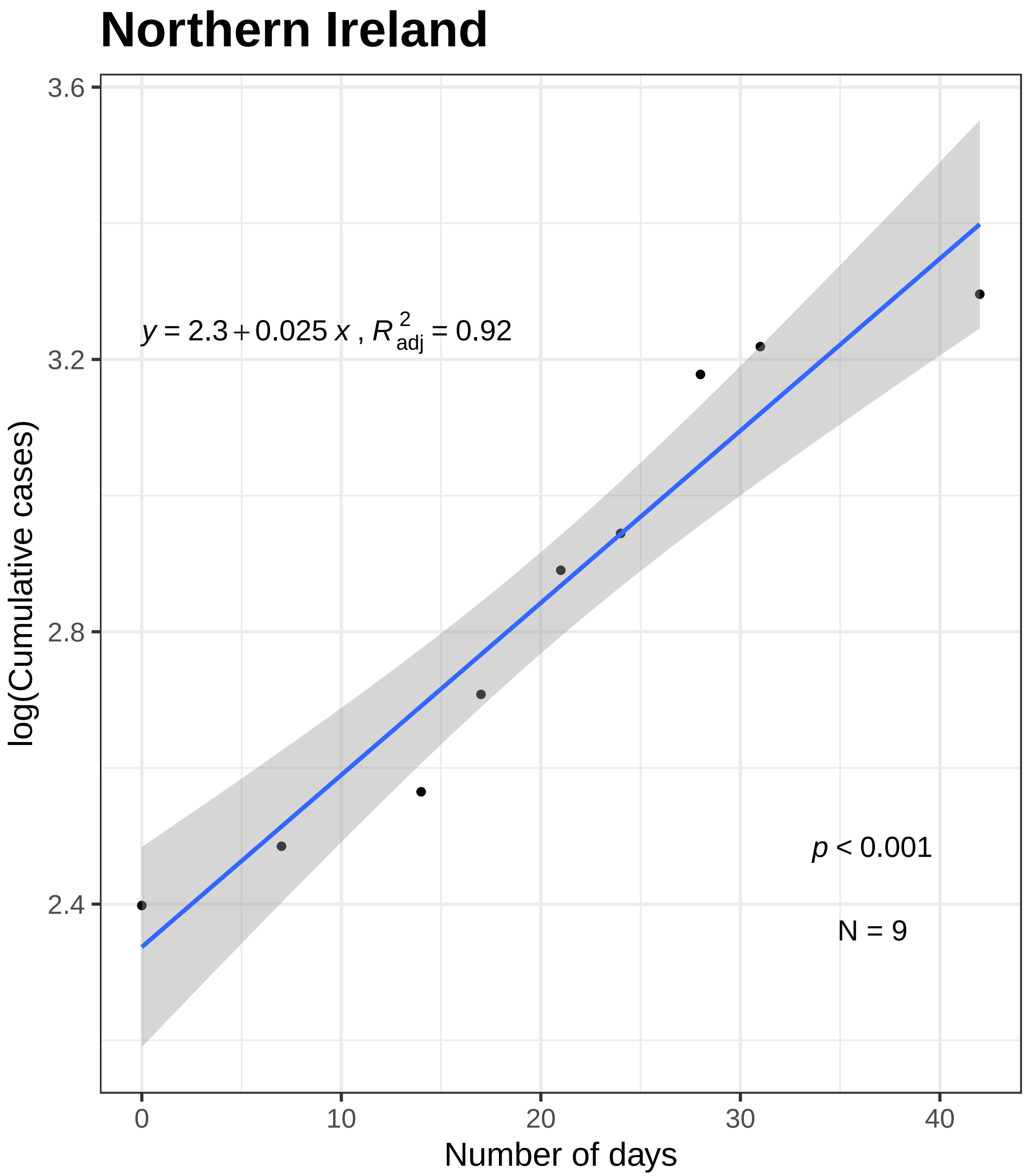


$y = 4 + 0.059\,x$, $R^2_{adj} = 0.85$
N = 69
$p < 0.001$
8
6
4
0
25
50
75
log(Cumulative cases)
Number of days

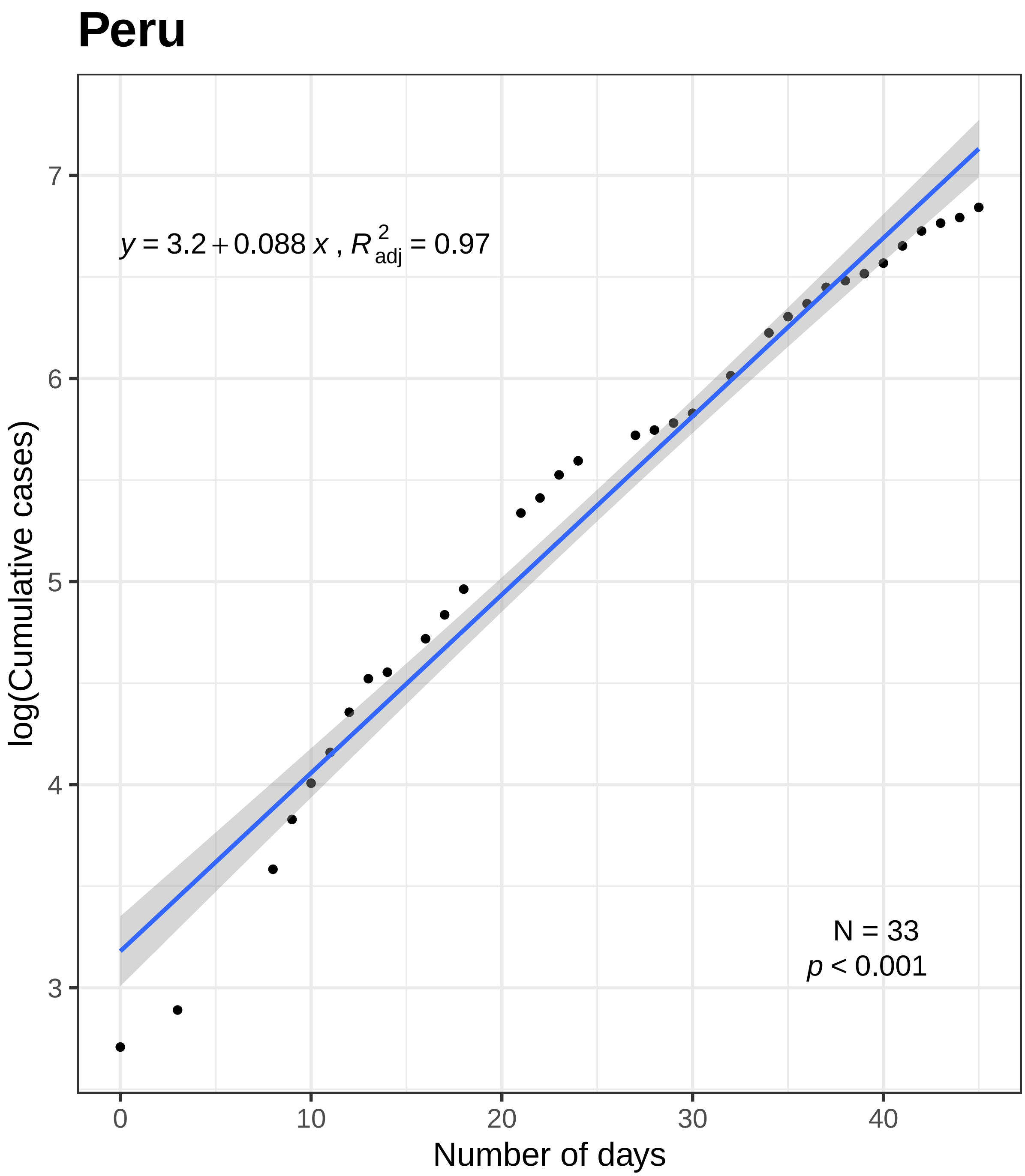

Italy
$y = 2.9 + 0.05\,x$, $R^2_{adj} = 0.94$
N = 31
$p < 0.001$
log(Cumulative cases)
7
6
5
4
3
0
20
40
60
80
Number of days

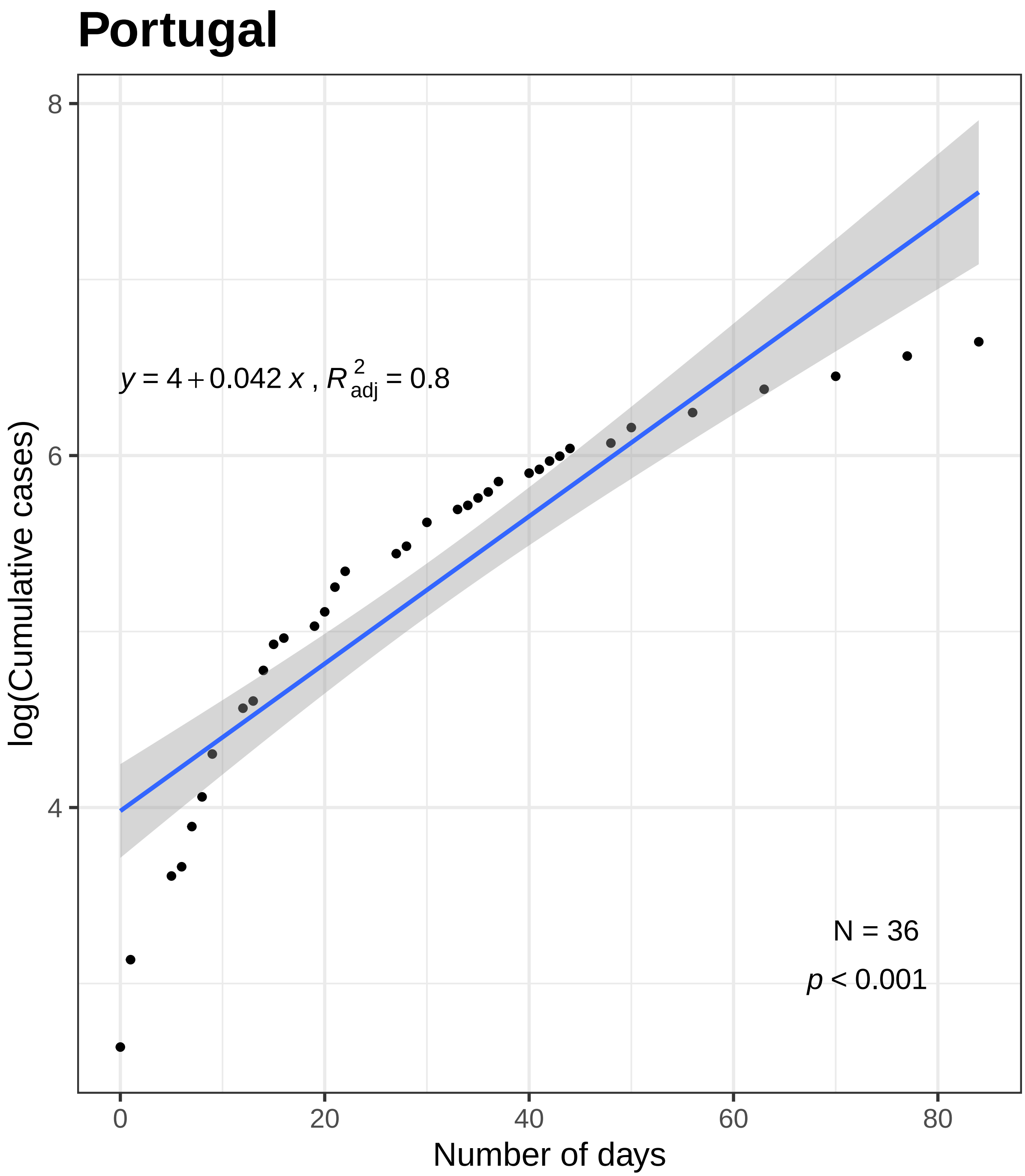

Mexico
y = 2.6 + 0.057 x , R²adj = 0.95
N = 10
p < 0.001
log(Cumulative cases)
5
4
3
0
10
20
30
40
50
Number of days


Netherlands
$y = 3.4 + 0.051\,x$, $R^2_{adj} = 0.92$
N = 24
$p < 0.001$
log(Cumulative cases)
Number of days
8
6
4
0
20
40
60
80

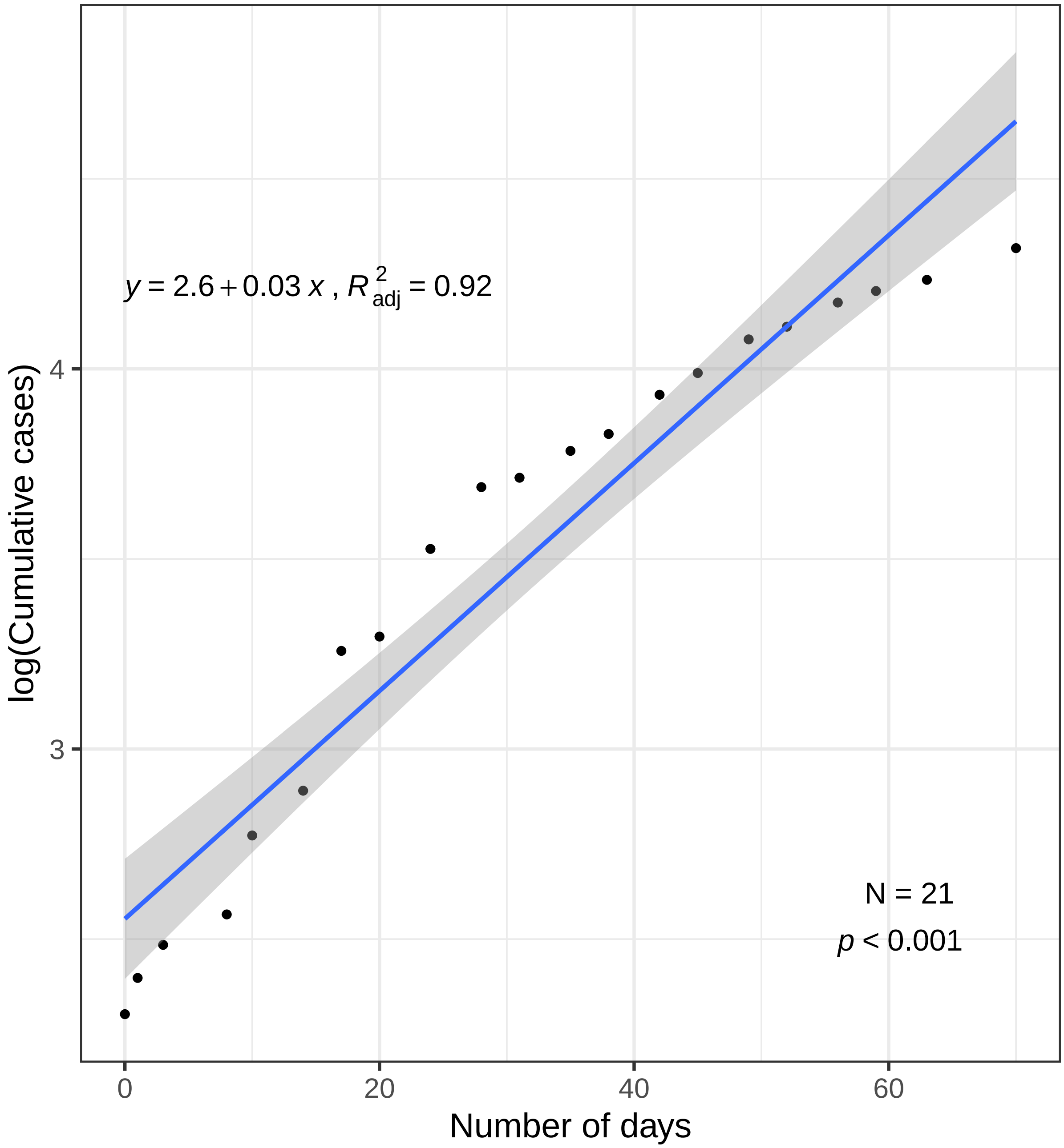


Northern Ireland
$y = 2.3 + 0.025\,x$, $R^2_{adj} = 0.92$
$p < 0.001$
N = 9
log(Cumulative cases)
Number of days
3.6
3.2
2.8
2.4
0
10
20
30
40

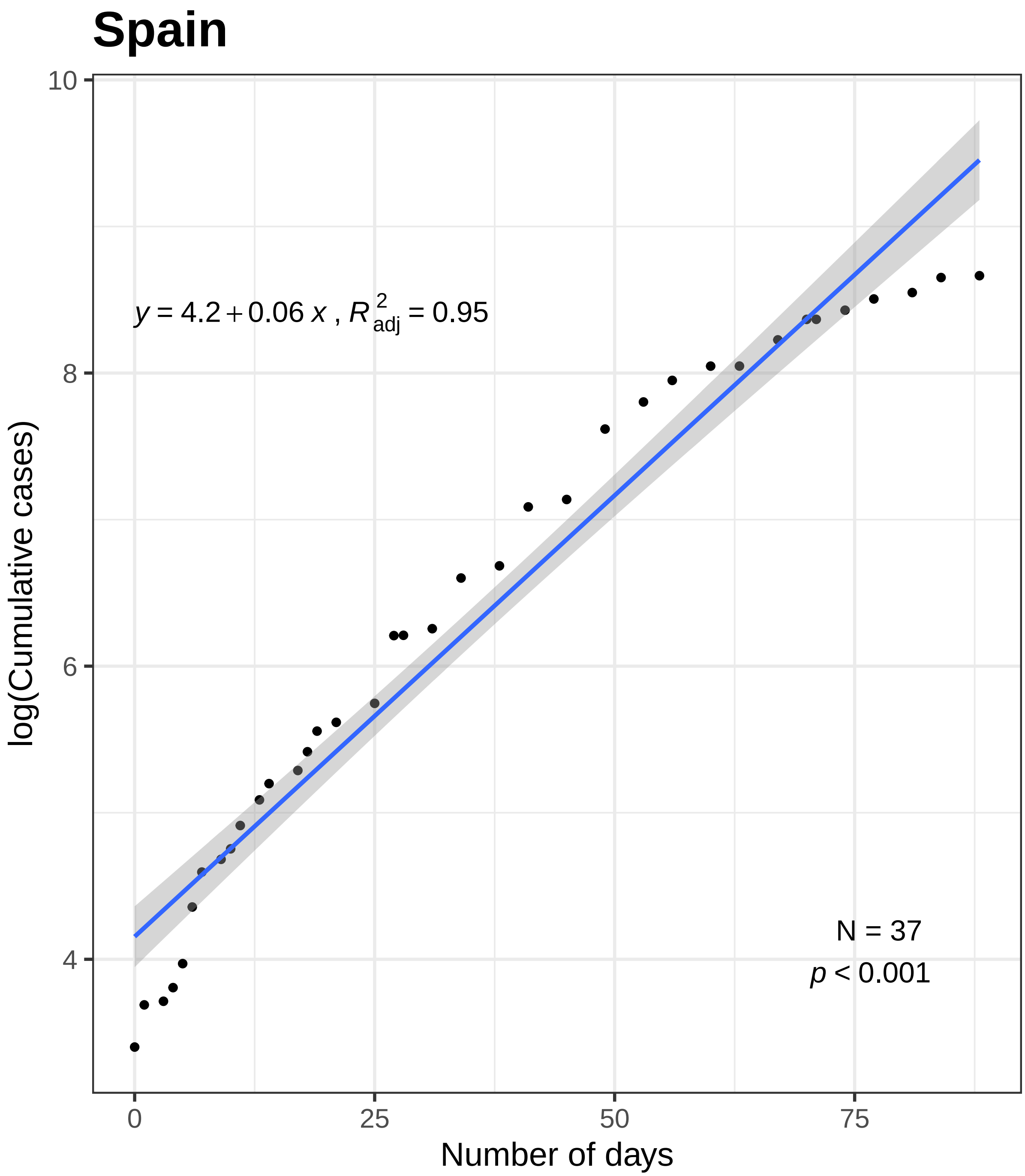

Peru
y = 3.2 + 0.088 x , R 2 adj = 0.97
N = 33
p < 0.001
log(Cumulative cases)
Number of days
7
6
5
4
3
0
10
20
30
40

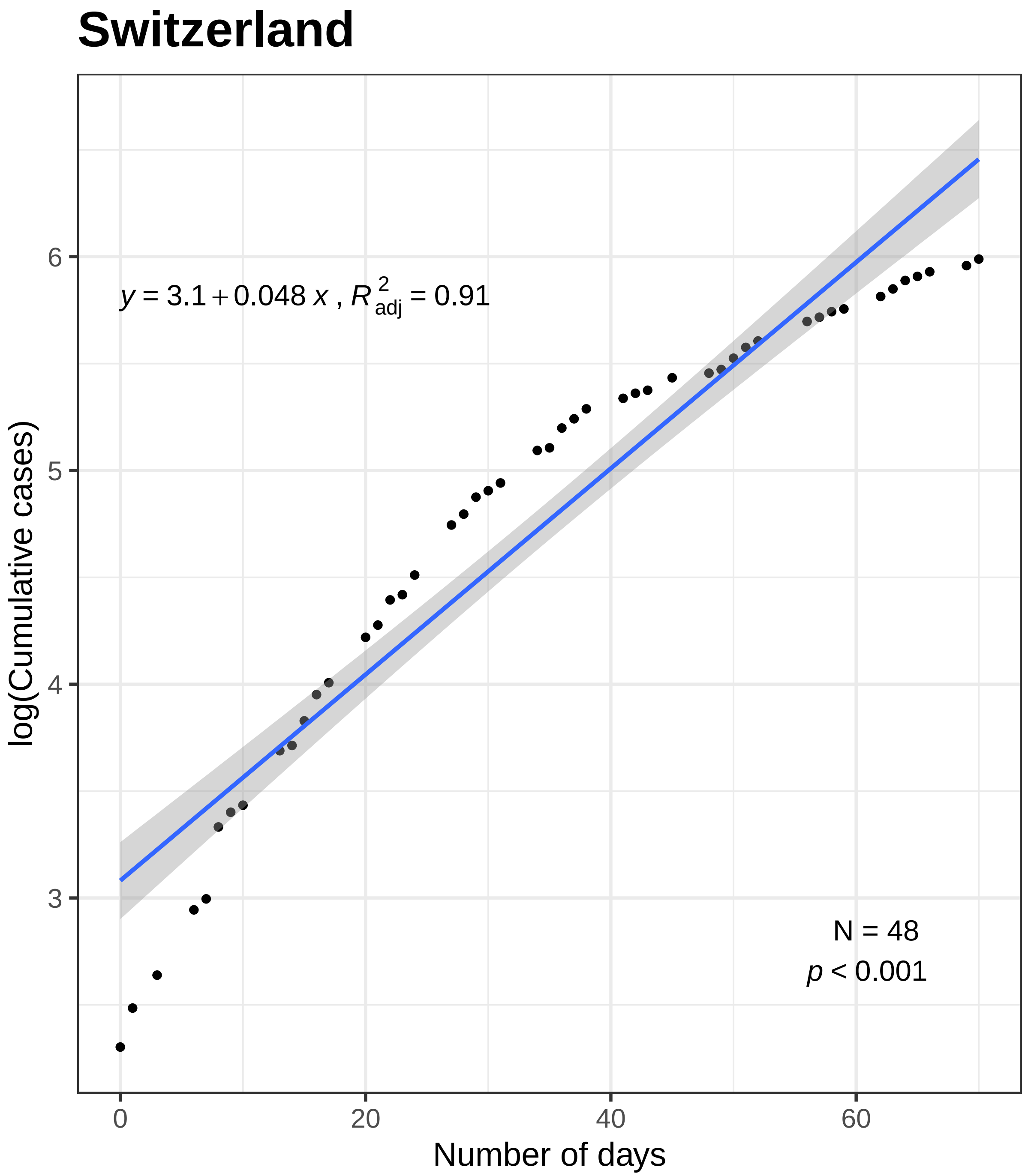

Portugal
$y = 4 + 0.042\,x$, $R^2_{adj} = 0.8$
N = 36
$p < 0.001$
log(Cumulative cases)
8
6
4
0
20
40
60
80
Number of days

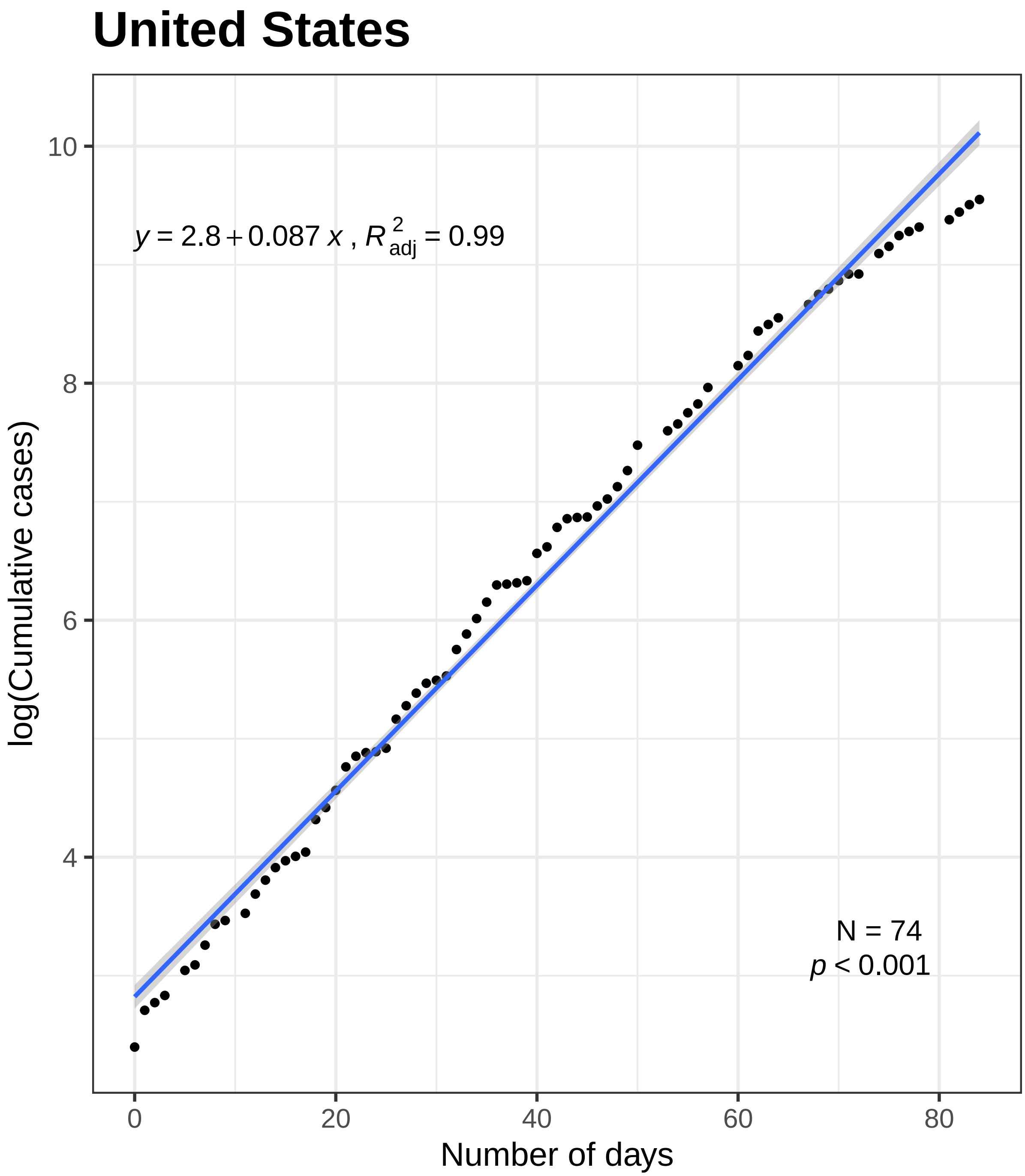
Scotland

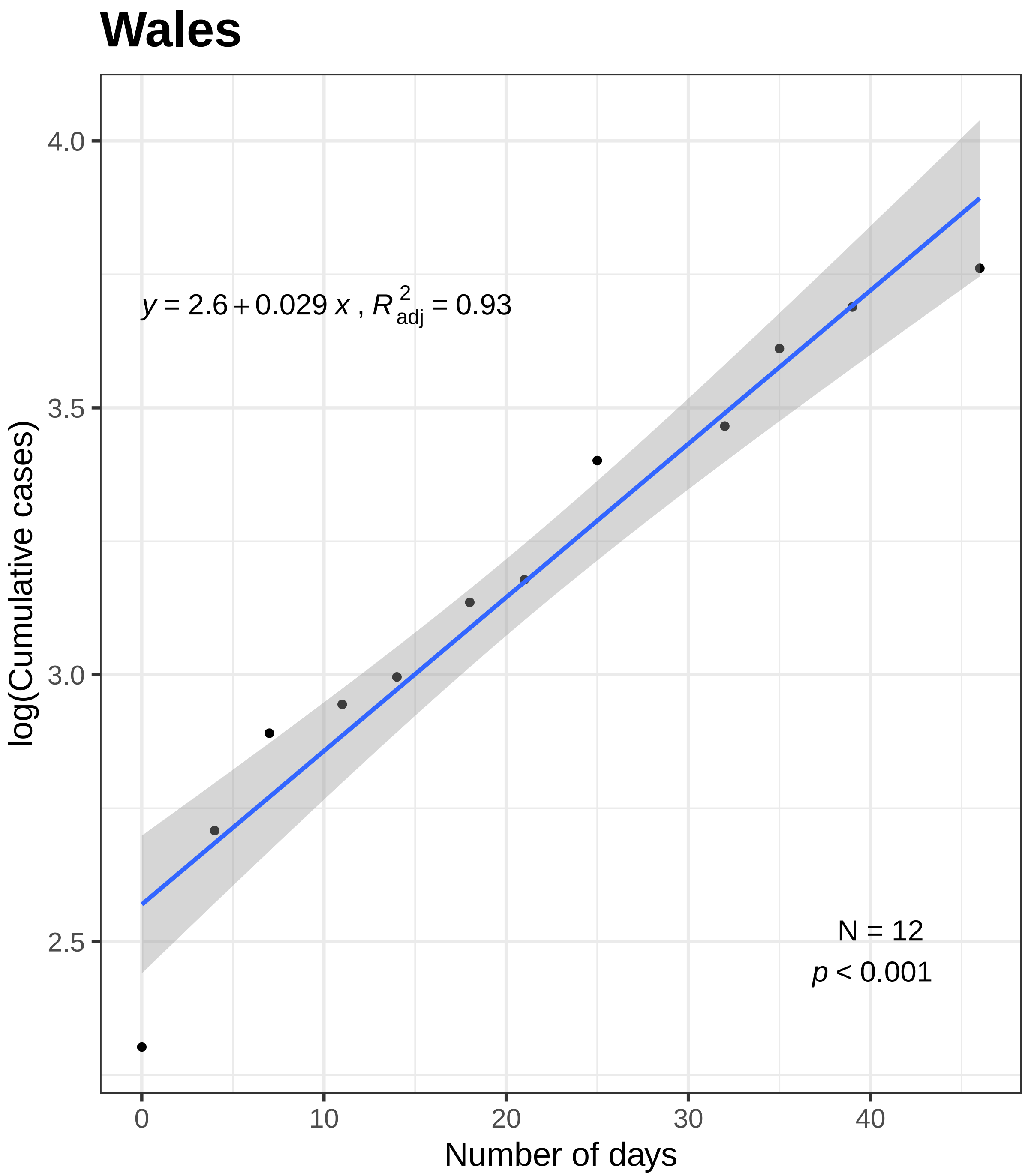


$y = 2.6 + 0.03\,x$, $R^2_{adj} = 0.92$
N = 21
$p < 0.001$
log(Cumulative cases)
4
3
0
20
40
60
Number of days


Spain
$y = 4.2 + 0.06\,x$, $R^2_{adj} = 0.95$
N = 37
$p < 0.001$
log(Cumulative cases)
Number of days
10
8
6
4
0
25
50
75


Switzerland
$y = 3.1 + 0.048\,x$, $R^2_{adj} = 0.91$
N = 48
$p < 0.001$
6
5
4
3
0
20
40
60
log(Cumulative cases)
Number of days


United States
$y = 2.8 + 0.087\,x$, $R^2_{adj} = 0.99$
N = 74
$p < 0.001$
log(Cumulative cases)
Number of days
10
8
6
4
0
20
40
60
80



Wales
4.0
3.5
3.0
2.5
log(Cumulative cases)
y = 2.6 + 0.029 x , R²adj = 0.93
N = 12
p < 0.001
0
10
20
30
40
Number of days

B Estimation of the duplication time

Given two cumulative counts: C_1, C_2, obtained at two different times: t_1, t_2, their ratio Q is defined as follows:

$$Q = \frac{C_2}{C_1} = \frac{\alpha e^{(\gamma \log \beta) t_2}}{\alpha e^{(\gamma \log \beta) t_1}} = \alpha e^{(\gamma \log \beta)(t_2 - t_1)} \tag{4}$$

When $Q = 2$, then the difference $(t_2 - t_1)$ is defined as the duplication time T_d: the time it takes for the count to double in size with respect to an initial value.

Using that definition, and employing Equation 3:

$$\begin{aligned}
\log Q &= \log \frac{C_2}{C_1} &(5)\\
&= \log C_2 - \log C_1 &(6)\\
&= (A + Bt_2) - (A - Bt_1) &(7)\\
&= B(t_2 - t_1) &(8)\\
&= B(T_d) &(9)
\end{aligned}$$

Finally we can define T_d in terms of the slope (B), if $Q = 2$, then:

$$T_d = \frac{\log 2}{B} \tag{10}$$

Using the regression results of the slope and its standard error, we can calculate T_d and its C.I., obtaining:

Table 3: Duplication time estimates for selected countries

Country	N° Obs.[1]	Slope	S.E.$_{slope}$	95% CI$_{slope}$	$\widehat{T}_d$	95% CI$_{\widehat{T}_d}$
Brazil	50	0.0960	0.0031	[0.0898 - 0.1022]	7.2206	[6.7852 - 7.7156]
Peru	33	0.0878	0.0030	[0.0820 - 0.0936]	7.8941	[7.4058 - 8.4514]
United States	74	0.0868	0.0011	[0.0847 - 0.0889]	7.9850	[7.7979 - 8.1813]
France	27	0.0611	0.0035	[0.0543 - 0.0678]	11.3487	[10.2172 - 12.7621]
Spain	37	0.0602	0.0023	[0.0558 - 0.0647]	11.5111	[10.7195 - 12.4289]
Germany	69	0.0589	0.0030	[0.0531 - 0.0648]	11.7623	[10.6958 - 13.0650]
Mexico	10	0.0571	0.0042	[0.0488 - 0.0654]	12.1380	[10.6040 - 14.1909]
Belgium	14	0.0509	0.0034	[0.0443 - 0.0576]	13.6151	[12.0404 - 15.6636]
Netherlands	24	0.0508	0.0032	[0.0446 - 0.0569]	13.6548	[12.1718 - 15.5492]
Italy	31	0.0501	0.0024	[0.0454 - 0.0548]	13.8356	[12.6466 - 15.2712]
England	32	0.0498	0.0035	[0.0430 - 0.0567]	13.9047	[12.2222 - 16.1244]
Switzerland	48	0.0482	0.0022	[0.0439 - 0.0526]	14.3764	[13.1856 - 15.8037]
Austria	16	0.0466	0.0031	[0.0406 - 0.0527]	14.8628	[13.1637 - 17.0656]
Portugal	36	0.0419	0.0035	[0.0350 - 0.0487]	16.5596	[14.2205 - 19.8199]
Canada	48	0.0411	0.0018	[0.0376 - 0.0446]	16.8702	[15.5349 - 18.4566]
Scotland	21	0.0300	0.0020	[0.0261 - 0.0339]	23.1295	[20.4743 - 26.5758]
Wales	12	0.0288	0.0023	[0.0243 - 0.0332]	24.1057	[20.8500 - 28.5662]
Northern Ireland	9	0.0253	0.0026	[0.0201 - 0.0304]	27.4195	[22.7908 - 34.4076]

[1] Number of days with reports of confirmed cases in the date range

C Estimation of the effective reproduction number

According to (Bonifazi et al. 2021) there is a functional relation between the effective reproduction number (R_t), and the duplication time, of the form:

$$\widehat{R}_t = e^{(g \log 2)/\widehat{T}_d} \tag{11}$$

where: g is the generation time, and $\widehat{T}_d$ is the estimate of the duplication time.

Combining Equation 10 and Equation 11, we can derive

$$\widehat{R}_t = e^{(g \log 2)/(\log 2/B)} = e^{gB} \tag{12}$$

A recent article (Guzzetta et al. 2022), gives an early estimate for the generation time of the current MPXV outbreak of 12.5 days (95% CI: [7.5 - 17.3]). Using Equation 12, along with our estimate for the slope (B) and the published estimate for g with its 95% CI, we can compute a possible value of R_t:

Table 4: Estimates of R_t for selected countries

Country	Slope	R_t(mean)[1]	R_t(lower)[2]	R_t(upper)[3]
Brazil	0.096	3.320	2.054	5.263
Peru	0.088	2.997	1.932	4.568
United States	0.087	2.960	1.918	4.489
France	0.061	2.146	1.581	2.877
Spain	0.060	2.123	1.571	2.834
Germany	0.059	2.089	1.556	2.772
Mexico	0.057	2.042	1.535	2.686
Belgium	0.051	1.890	1.465	2.413
Netherlands	0.051	1.886	1.463	2.407
Italy	0.050	1.871	1.456	2.379
England	0.050	1.865	1.453	2.369
Switzerland	0.048	1.827	1.436	2.303
Austria	0.047	1.791	1.419	2.241
Portugal	0.042	1.687	1.369	2.063
Canada	0.041	1.671	1.361	2.036
Scotland	0.030	1.454	1.252	1.679
Wales	0.029	1.433	1.241	1.645
Northern Ireland	0.025	1.372	1.209	1.549

[1] Using the mean estimate of 12.5 days

[2] Using the lower estimate of 7.5 days

[3] Using the higher estimate of 17.3 days

D Cumulative incidence for all countries with confirmed cases

In the following two tables, we show the cumulative incidence up to the most current complete epidemiological week (2022W33), separating those countries with 10 or more confirmed cases in total, from those with less than 10 cases.

Table 5: Cumulative incidence per million for countries at least 10 confirmed cases

Country	**Date of first confirmed case**[13]	**Total cases**[13]	**Population (2022)**[4]	**Incidence (per million)**[3]
Africa				
Democratic Republic Of The Congo	2022-05-08	163	99,010,212	1.646
Ghana	2022-06-08	47	33,475,870	1.404
Nigeria	2022-01-31[2]	172	218,541,212	0.787
Asia				
Israel	2022-05-21	194	9,038,309	21.464
Singapore	2022-06-20	15	5,975,689	2.510
United Arab Emirates	2022-05-24	16	9,441,129	1.695
India	2022-07-14	10	1,417,173,173	0.007
Europe				
Spain	2022-05-18	5,792	47,558,630	121.787
Portugal	2022-05-17	770	10,270,865	74.969
Luxembourg	2022-06-16	45	647,599	69.487
Netherlands	2022-05-20	1,087	17,564,014	61.888
Malta	2022-05-28	31	533,286	58.130
Belgium	2022-05-19	624	11,655,930	53.535
Switzerland	2022-05-21	399	8,740,472	45.650
England	2022-05-06	3,050	67,508,936	45.179
France	2022-05-19	2,873	64,626,628	44.455
Germany	2022-05-19	3,266	83,369,843	39.175
Iceland	2022-06-15	12	372,899	32.180
Denmark	2022-05-23	163	5,882,261	27.710
Austria	2022-05-23	217	8,939,617	24.274
Ireland	2022-05-27	113	5,023,109	22.496
Slovenia	2022-05-24	43	2,119,844	20.285
Norway	2022-05-31	76	5,434,319	13.985
Sweden	2022-05-19	139	10,549,347	13.176
Italy	2022-05-19	689	59,037,474	11.671
Hungary	2022-05-31	62	9,967,308	6.220
Greece	2022-06-08	50	10,384,971	4.815

Table 5: Cumulative incidence per million for countries at least 10 confirmed cases *(continued)*

Country	**Date of first confirmed case**[1,3]	**Total cases**[1,3]	**Population (2022)**[4]	**Incidence (per million)**[3]
Serbia	2022-06-17	31	7,221,365	4.293
Croatia	2022-06-23	17	4,030,358	4.218
Finland	2022-05-27	22	5,540,745	3.971
Czech Republic	2022-05-24	36	10,493,986	3.431
Poland	2022-06-10	104	39,857,145	2.609
Slovakia	2022-07-07	10	5,643,453	1.772
Romania	2022-06-13	33	19,659,267	1.679
Scotland	2022-05-23	75	67,508,936	1.111
Wales	2022-05-26	43	67,508,936	0.637
Northern Ireland	2022-05-26	27	67,508,936	0.400
Latin America and the Caribbean				
Peru	2022-06-26	937	34,049,588	27.519
Puerto Rico	2022-06-29	66	3,252,407	20.293
Brazil	2022-06-08	3,656	215,313,498	16.980
Chile	2022-06-17	189	19,603,733	9.641
Bolivia	2022-08-01	37	12,224,110	3.027
Colombia	2022-06-23	129	51,874,024	2.487
Mexico	2022-05-28	252	127,504,125	1.976
Argentina	2022-05-27	72	45,510,318	1.582
Ecuador	2022-07-06	20	18,001,000	1.111
Northern America				
United States	2022-05-18	14,050	338,289,857	41.532
Canada	2022-05-19	1,125	38,454,327	29.255
Oceania				
Australia	2022-05-20	90	26,177,413	3.438

[1] Source: Global.health Monkeypox data repository

[2] Reports earlier than May 2022 are from endemic areas

[3] As of complete epidemiological week #33 of 2022.

[4] Source: UN 2022 Revision of World Population Prospects

Table 6: Cumulative incidence per million for countries with less than 10 confirmed cases

Country	Date of first confirmed case[13]	Total cases[13]	Population (2022)[4]	Incidence (per million)[3]
Africa				
Central African Republic	2022-03-04[2]	8	5,579,144	1.434
Republic of Congo	2022-04-12[2]	3	5,970,424	0.502
Liberia	2022-07-23	2	5,302,681	0.377
Cameroon	2022-02-17[2]	7	27,914,536	0.251
Benin	2022-06-14	3	13,352,864	0.225
South Africa	2022-06-22	5	59,893,885	0.083
Sudan	2022-07-31	2	46,874,204	0.043
Morocco	2022-06-02	1	37,457,971	0.027
Asia				
Cyprus	2022-08-02	4	1,251,488	3.196
Qatar	2022-07-20	3	2,695,122	1.113
Lebanon	2022-06-20	6	5,489,739	1.093
Georgia	2022-06-15	2	3,744,385	0.534
Saudi Arabia	2022-07-14	6	36,408,820	0.165
Taiwan	2022-06-24	3	23,893,394	0.126
Thailand	2022-07-21	5	71,697,030	0.070
Turkey	2022-06-30	5	85,341,241	0.059
Japan	2022-07-25	4	123,951,692	0.032
Philippines	2022-07-28	3	115,559,009	0.026
South Korea	2022-06-22	1	51,815,810	0.019
Iran	2022-08-16	1	88,550,570	0.011
Europe				
Gibraltar	2022-06-01	6	32,649	183.773
Monaco	2022-07-21	3	36,469	82.262
Andorra	2022-07-25	4	79,824	50.110
Estonia	2022-06-28	9	1,326,062	6.787
Latvia	2022-06-03	4	1,850,651	2.161
Lithuania	2022-08-03	5	2,750,055	1.818
Montenegro	2022-08-01	1	627,082	1.595
Bosnia And Herzegovina	2022-07-13	3	3,233,526	0.928
Moldova	2022-08-08	2	3,272,996	0.611
Bulgaria	2022-06-23	4	6,781,953	0.590
Martinique	2022-07-15	2	64,626,628	0.031
Guadeloupe	2022-07-25	1	64,626,628	0.015

Table 6: Cumulative incidence per million for countries with less than 10 confirmed cases *(continued)*

Country	Date of first confirmed case[13]	Total cases[13]	Population (2022)[4]	Incidence (per million)[3]
Russia	2022-07-12	1	144,713,314	0.007
Latin America and the Caribbean				
Saint Martin (French part)	2022-08-01	1	31,791	31.455
Barbados	2022-07-16	1	281,635	3.551
Jamaica	2022-07-06	4	2,827,377	1.415
Panama	2022-07-05	5	4,408,581	1.134
Uruguay	2022-07-29	2	3,422,794	0.584
Costa Rica	2022-07-20	3	5,180,829	0.579
Dominican Republic	2022-07-06	6	11,228,821	0.534
Honduras	2022-08-13	3	10,432,860	0.288
Guatemala	2022-08-03	3	17,843,908	0.168
Venezuela	2022-06-12	1	28,301,696	0.035
Northern America				
Greenland	2022-08-09	2	56,466	35.420
Bermuda	2022-07-21	1	64,184	15.580
Oceania				
New Caledonia	2022-07-12	1	289,950	3.449
New Zealand	2022-07-09	4	5,185,288	0.771

[1] Source: Global.health Monkeypox data repository

[2] Reports earlier than May 2022 are from endemic areas

[3] As of complete epidemiological week #33 of 2022.

[4] Source: UN 2022 Revision of World Population Prospects

E References

Bonifazi, Gianluca, Luca Lista, Dario Menasce, Mauro Mezzetto, Daniele Pedrini, Roberto Spighi, and Antonio Zoccoli. 2021. "A Simplified Estimate of the Effective Reproduction Number R_t Using Its Relation with the Doubling Time and Application to Italian COVID-19 Data." *The European Physical Journal Plus* 136 (4): 386. https://doi.org/10.1140/epjp/s13360-021-01339-6.

Guzzetta, Giorgio, Alessia Mammone, Federica Ferraro, Anna Caraglia, Alessia Rapiti, Valentina Marziano, Piero Poletti, et al. 2022. "Early Estimates on Monkeypox Incubation Period, Generation Time and Reproduction Number in Italy, May-June 2022." arXiv.

https://doi.org/10.48550/arXiv.2207.13483.