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]
Belgium	2022-06-01	2022-08-08	13
Brazil	2022-06-22	2022-08-13	44
Canada	2022-05-23	2022-08-12	44
England	2022-05-20	2022-08-08	31
France	2022-05-28	2022-08-11	25
Germany	2022-05-24	2022-08-12	64
Italy	2022-05-26	2022-08-12	29
Netherlands	2022-05-25	2022-08-11	23
Northern Ireland	2022-07-04	2022-08-04	8
Peru	2022-07-04	2022-08-13	28
Portugal	2022-05-18	2022-08-10	36
Scotland	2022-06-06	2022-08-08	20
Spain	2022-05-20	2022-08-12	36
Switzerland	2022-06-07	2022-08-12	46
United States	2022-05-26	2022-08-12	70
Wales	2022-06-30	2022-08-08	11

[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*)

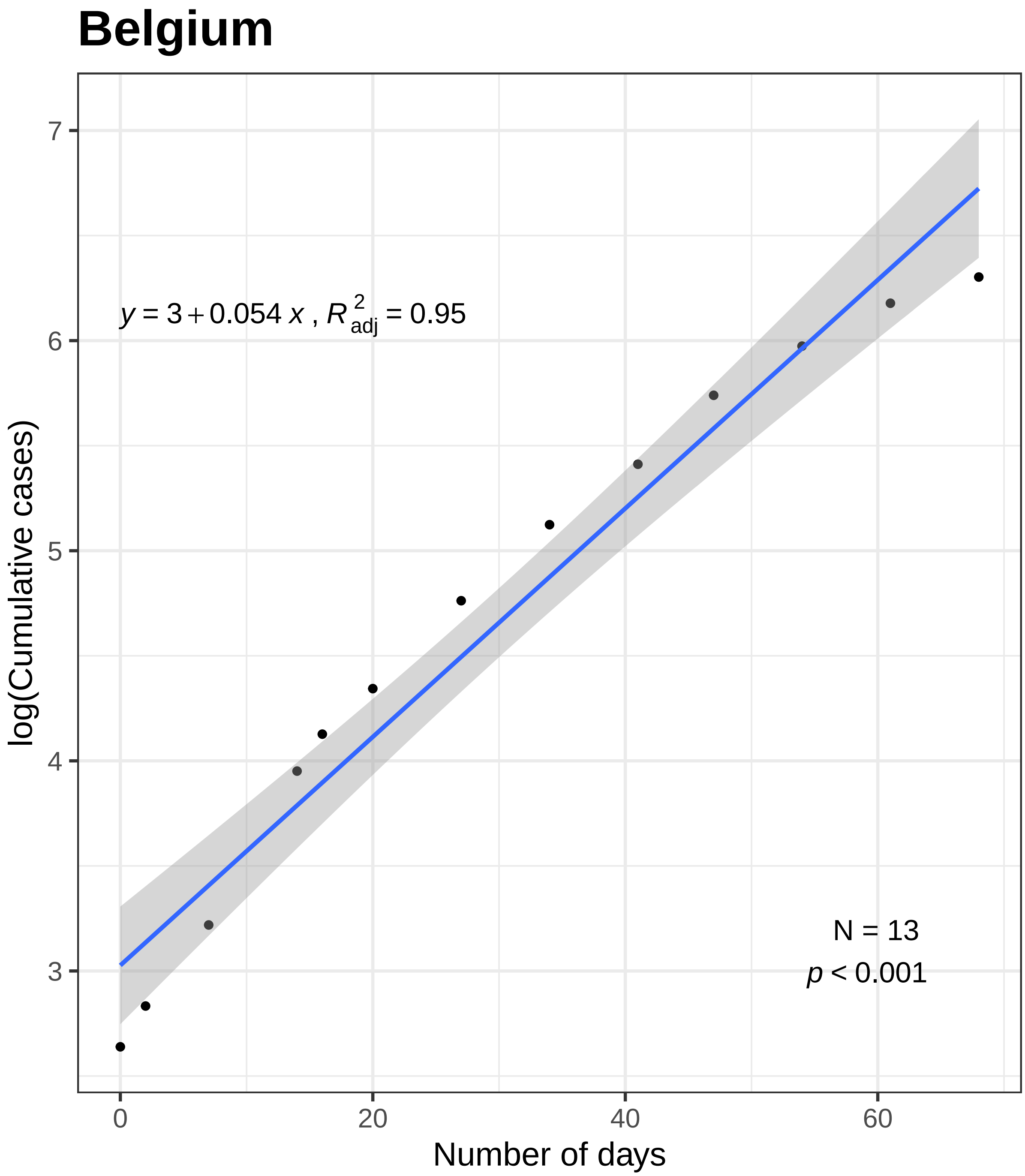
The results of the regressions can be seen in the following table

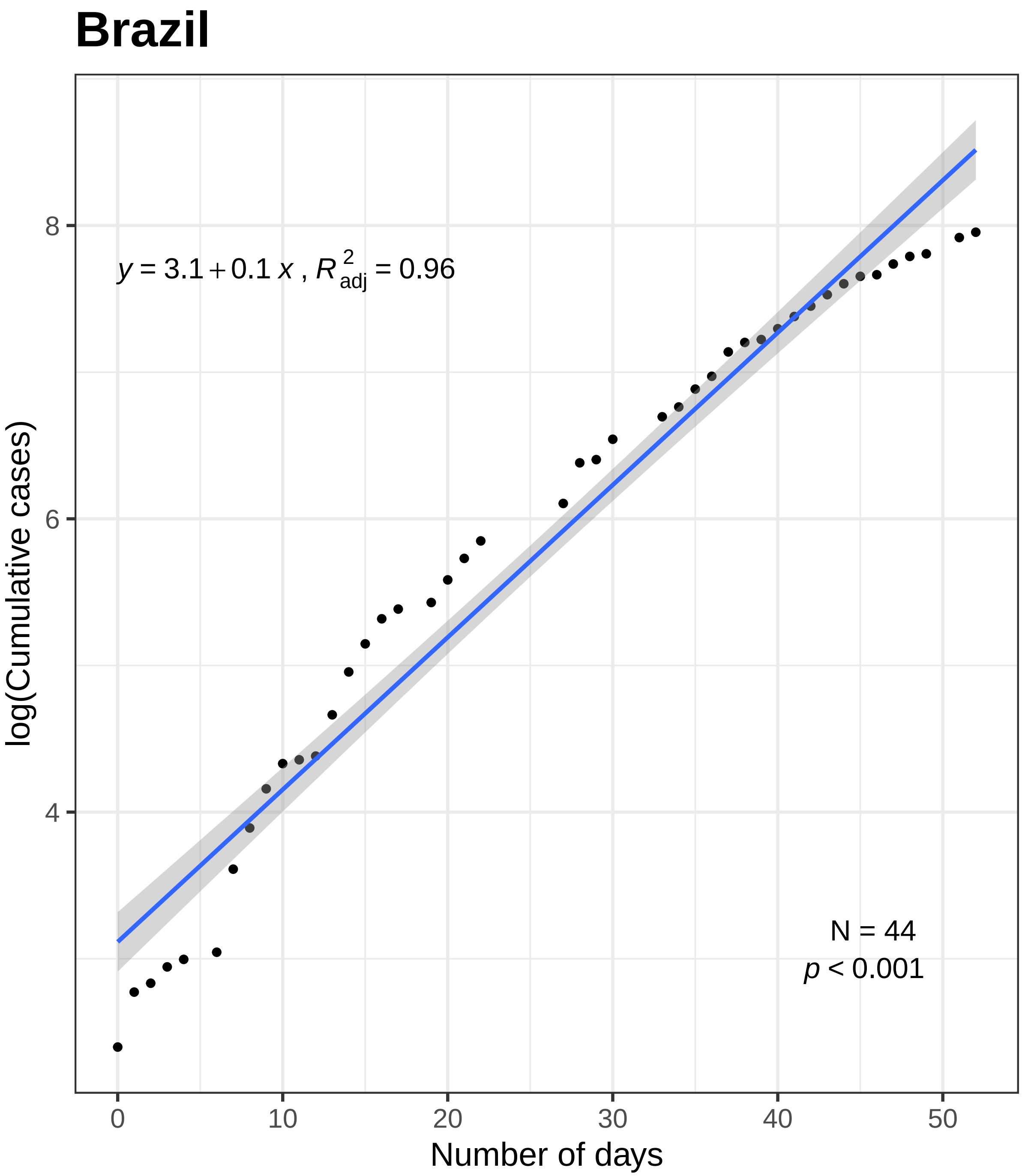
Table 2: Regression results for the selected countries

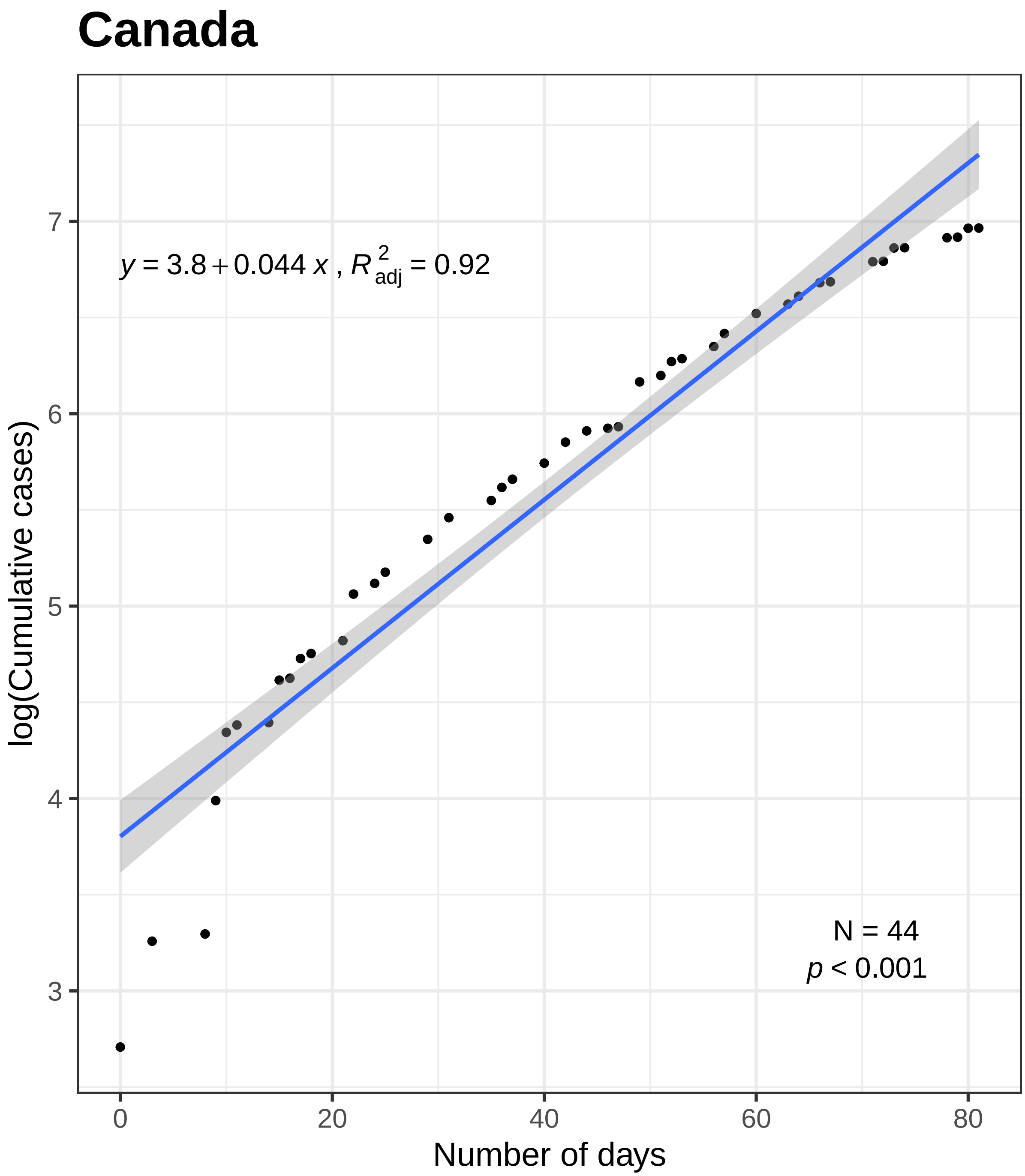
	Parameters				Statistics		
Country	Intercept	S.E.$_{inter.}$	Slope	S.E.$_{slope}$	R^2_{adj}	p-value	N° Obs.[1]
Belgium	3.0266	0.1272	0.0544	0.0034	0.9544	< 0.001	13
Brazil	3.1148	0.1004	0.1039	0.0033	0.9586	< 0.001	44
Canada	3.8025	0.0935	0.0438	0.0019	0.9224	< 0.001	44
England	4.4849	0.1487	0.0524	0.0036	0.8752	< 0.001	31
France	3.5983	0.1454	0.0659	0.0035	0.9360	< 0.001	25
Germany	3.8053	0.1434	0.0649	0.0031	0.8724	< 0.001	64
Italy	2.8321	0.1002	0.0536	0.0024	0.9459	< 0.001	29
Netherlands	3.3483	0.1476	0.0532	0.0031	0.9309	< 0.001	23
Northern Ireland	2.2927	0.0613	0.0285	0.0030	0.9263	< 0.001	8
Peru	3.0875	0.0857	0.0935	0.0034	0.9653	< 0.001	28
Portugal	3.9802	0.1311	0.0419	0.0035	0.8011	< 0.001	36
Scotland	2.5190	0.0712	0.0317	0.0020	0.9298	< 0.001	20
Spain	4.1179	0.0970	0.0619	0.0022	0.9558	< 0.001	36
Switzerland	3.0384	0.0882	0.0501	0.0023	0.9138	< 0.001	46
United States	2.7529	0.0413	0.0894	0.0009	0.9924	< 0.001	70
Wales	2.5418	0.0570	0.0309	0.0025	0.9362	< 0.001	11

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

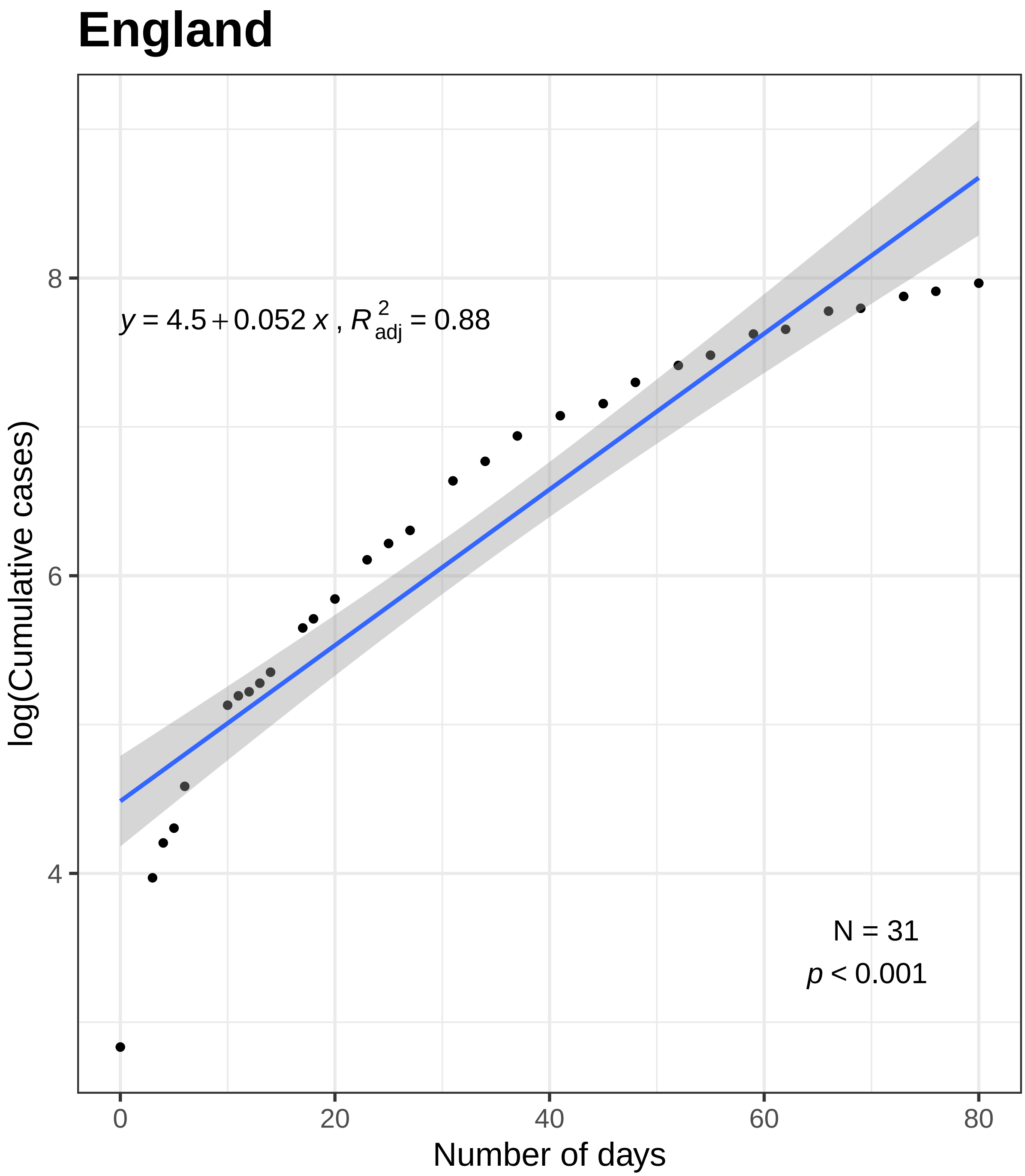
A.4 Plots of the regression results per country

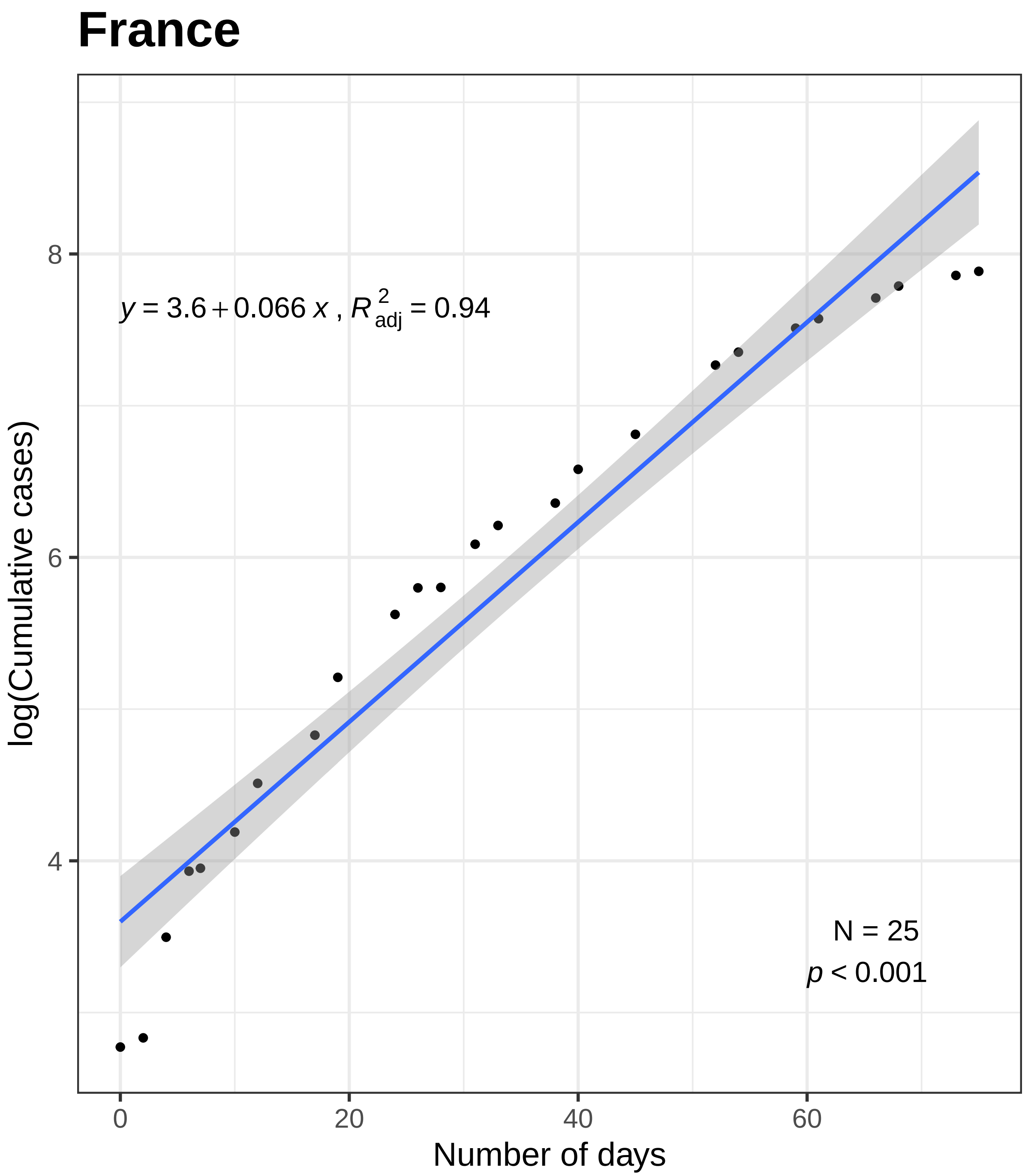


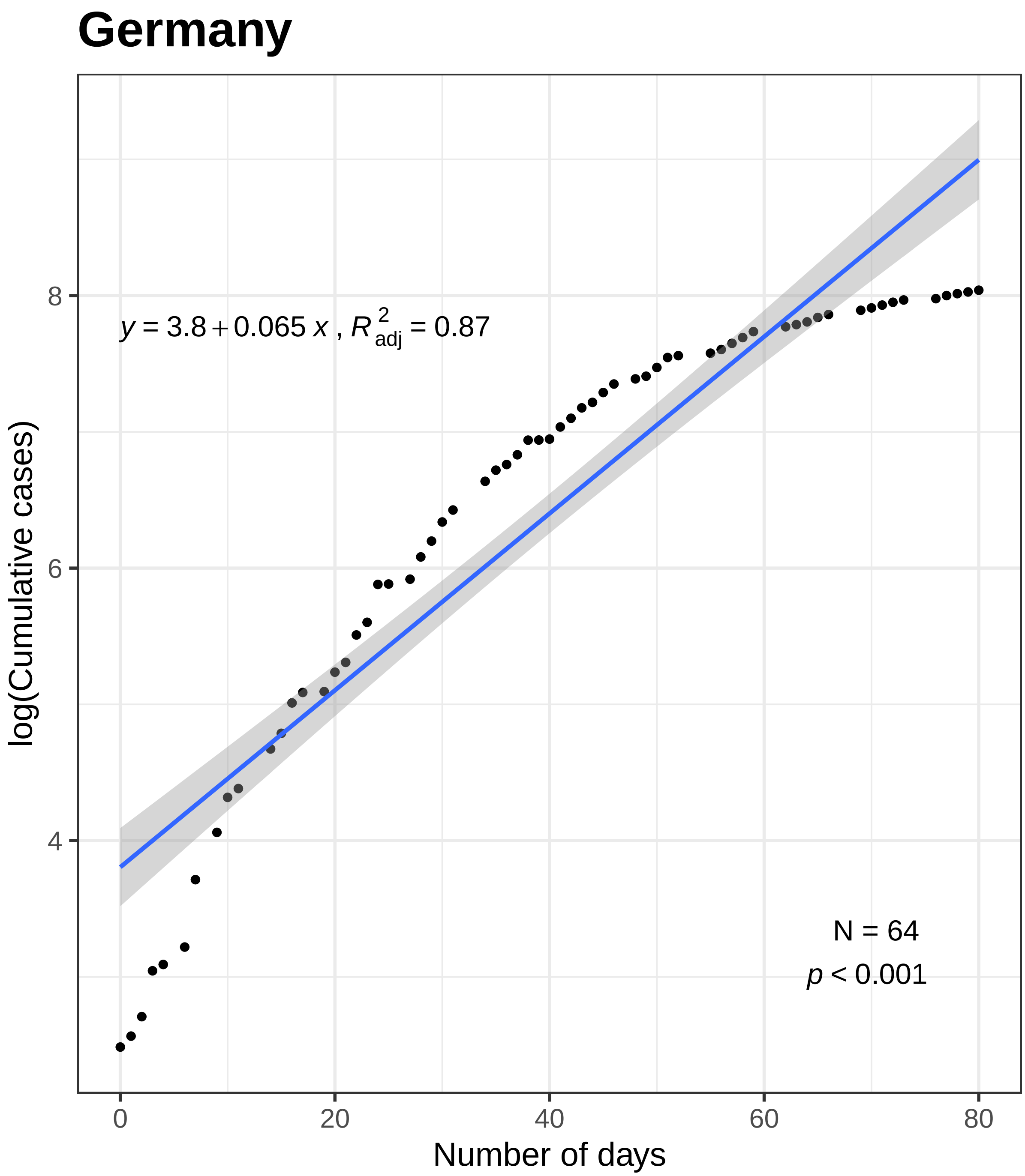

Brazil
$y = 3.1 + 0.1\,x$, $R^2_{adj} = 0.96$
N = 44
$p < 0.001$
log(Cumulative cases)
8
6
4
0
10
20
30
40
50
Number of days

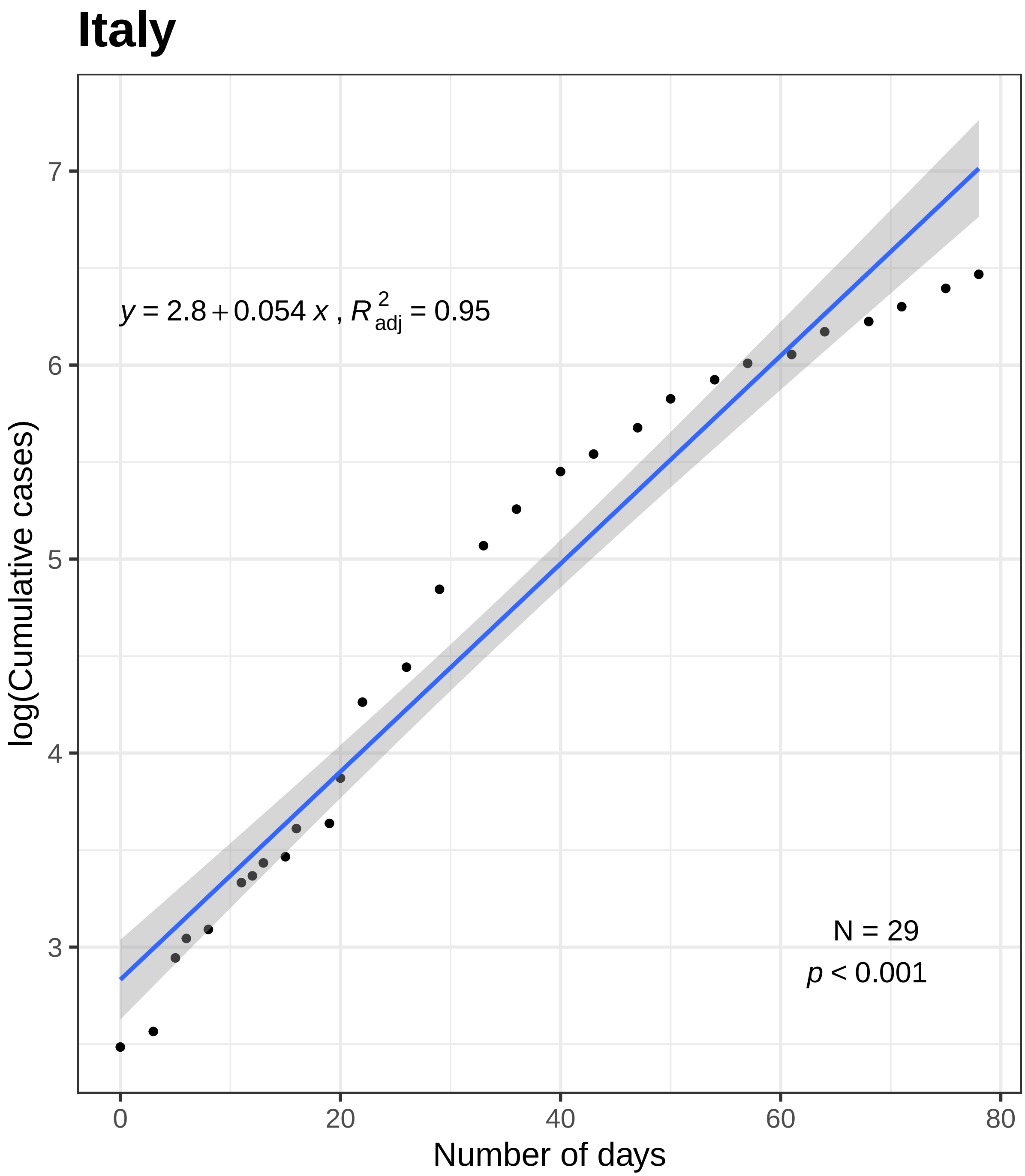


Canada
$y = 3.8 + 0.044\,x$, $R^2_{adj} = 0.92$
N = 44
p < 0.001
log(Cumulative cases)
7
6
5
4
3
0
20
40
60
80
Number of days

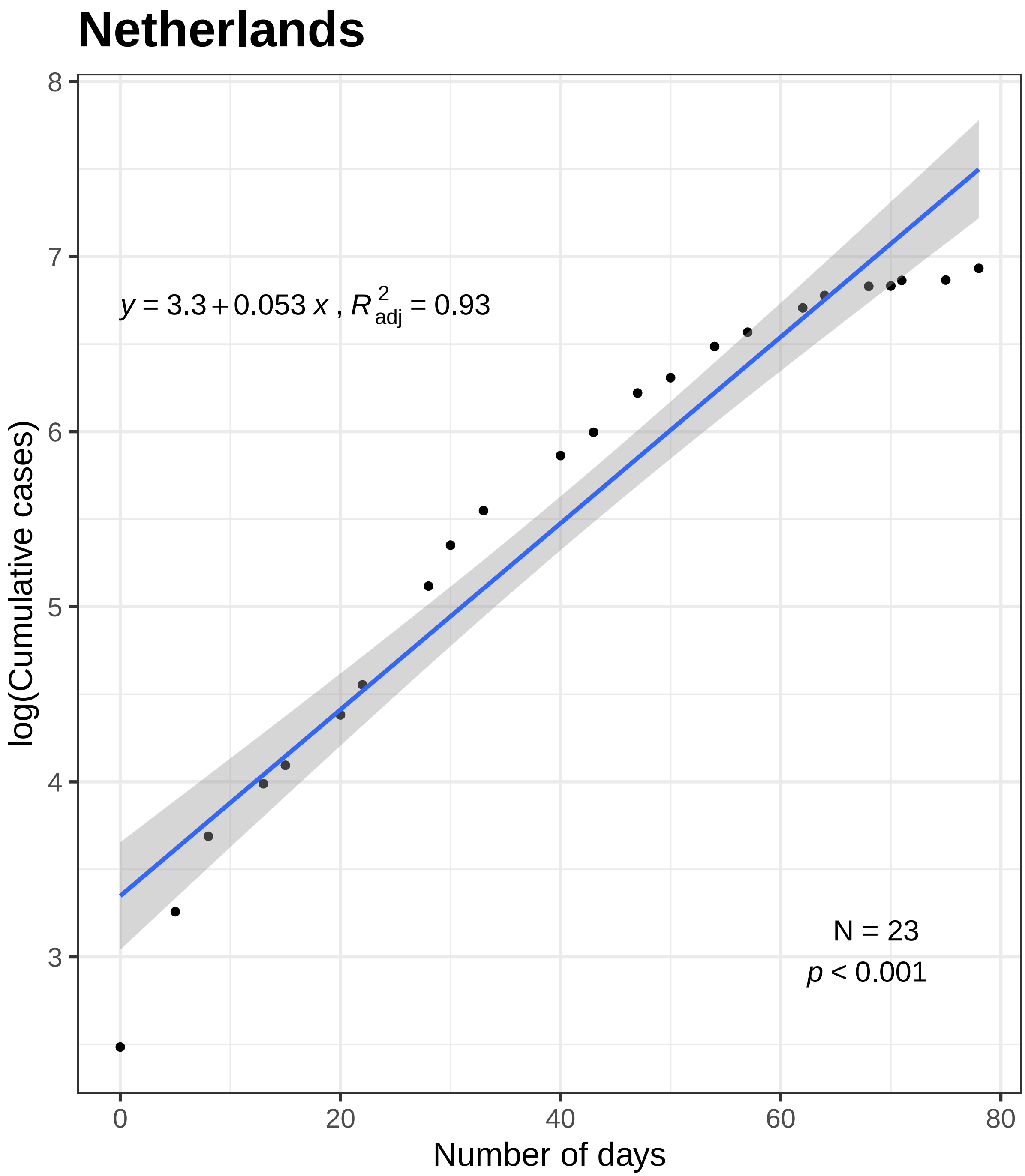

England
$y = 4.5 + 0.052\,x$, $R^2_{adj} = 0.88$
N = 31
$p < 0.001$
log(Cumulative cases)
Number of days
8
6
4
0
20
40
60
80

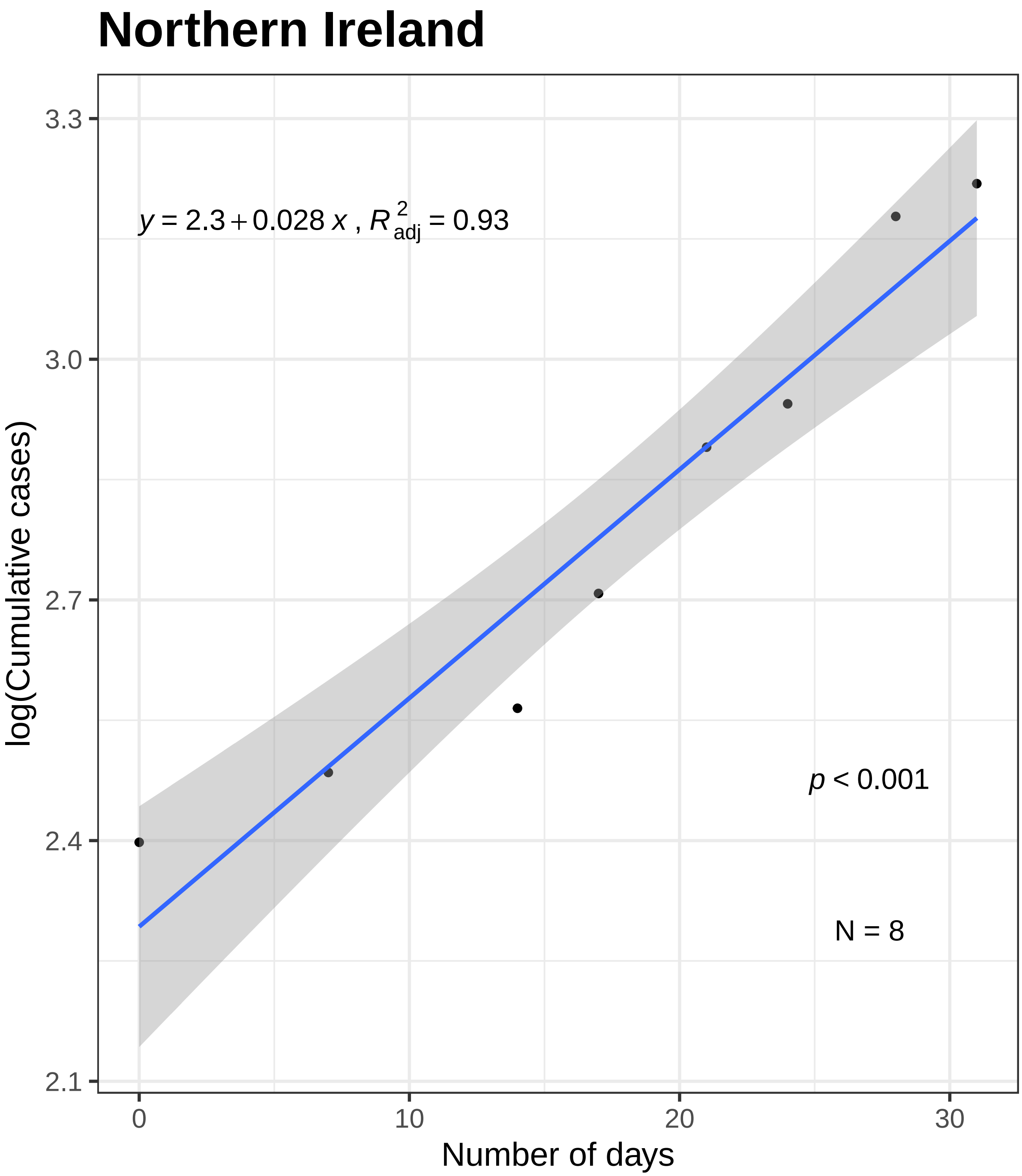

France
log(Cumulative cases)
8
6
4
$y = 3.6 + 0.066\,x$, $R^2_{adj} = 0.94$
N = 25
$p < 0.001$
0
20
40
60
Number of days

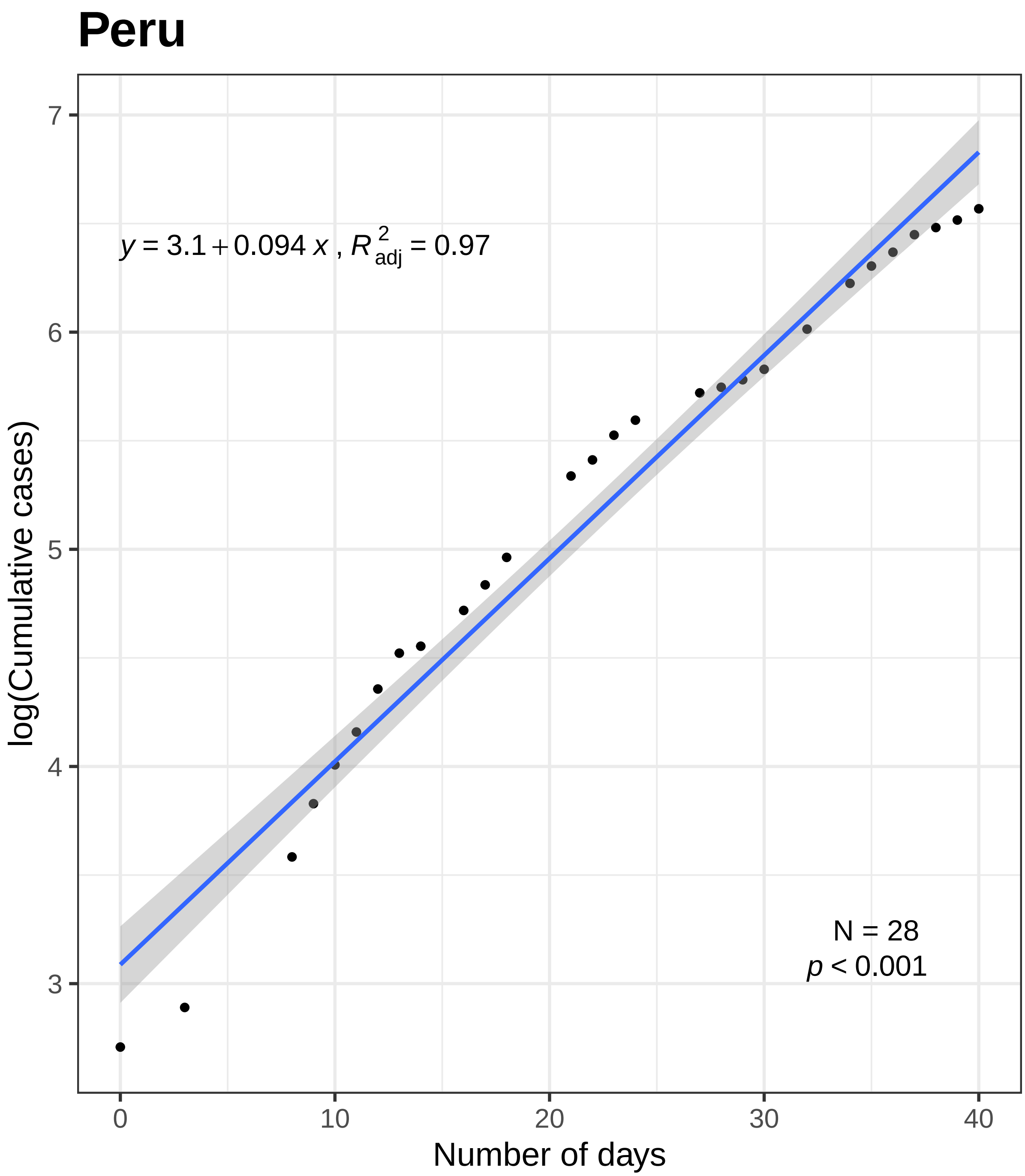

Germany
$y = 3.8 + 0.065\,x$, $R^2_{adj} = 0.87$
N = 64
p < 0.001
log(Cumulative cases)
Number of days
8
6
4
0
20
40
60
80



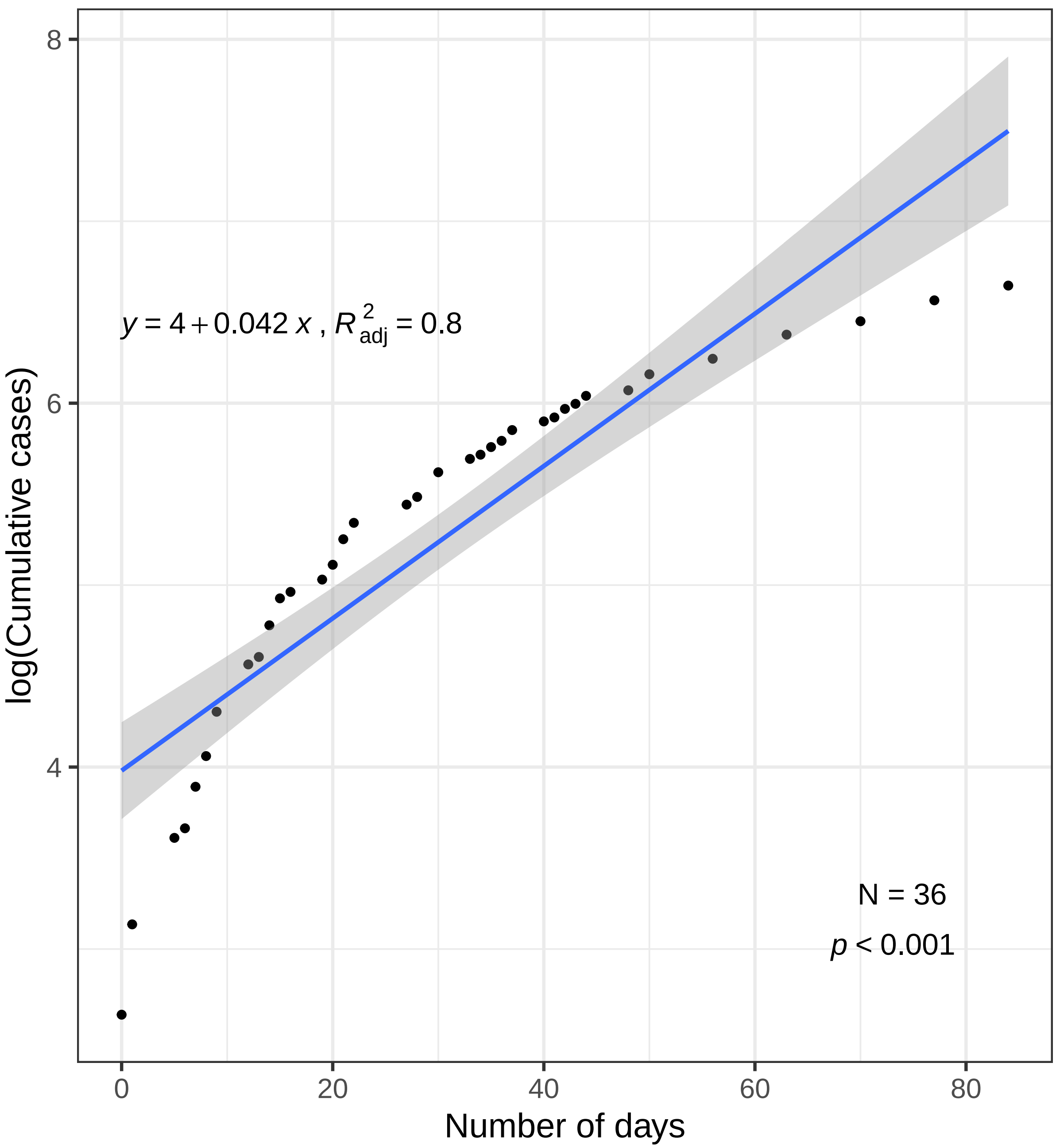
Italy
y = 2.8 + 0.054 x , R adj 2 = 0.95
N = 29
p < 0.001
log(Cumulative cases)
Number of days
7
6
5
4
3
0
20
40
60
80


Netherlands
log(Cumulative cases)
Number of days
y = 3.3 + 0.053 x , R²adj = 0.93
N = 23
p < 0.001
8
7
6
5
4
3
0
20
40
60
80

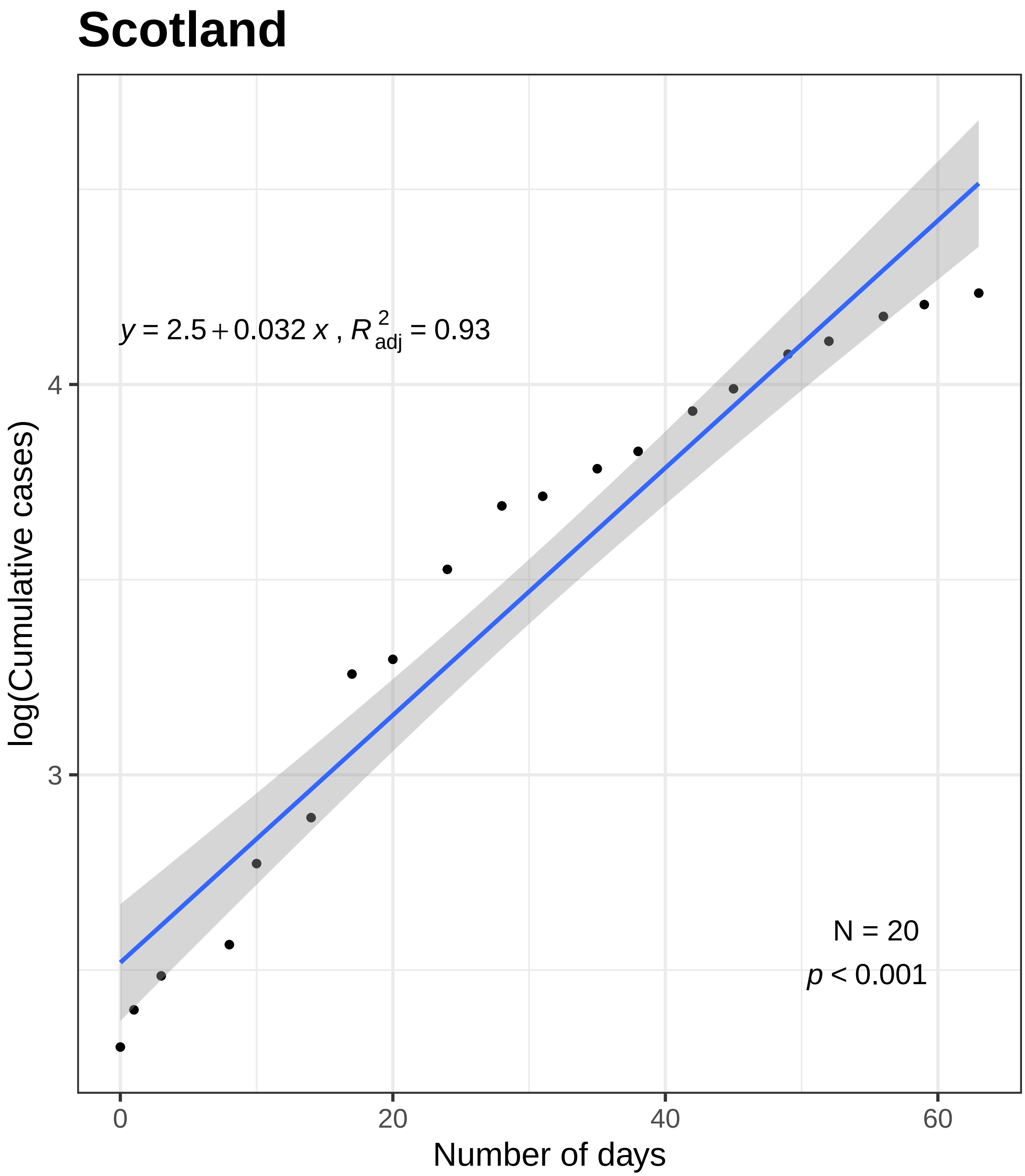

Northern Ireland
y = 2.3 + 0.028 x , R 2 adj = 0.93
p < 0.001
N = 8
3.3
3.0
2.7
2.4
2.1
log(Cumulative cases)
0
10
20
30
Number of days


Peru
y = 3.1 + 0.094 x , R2adj = 0.97
N = 28
p < 0.001
log(Cumulative cases)
Number of days
7
6
5
4
3
0
10
20
30
40

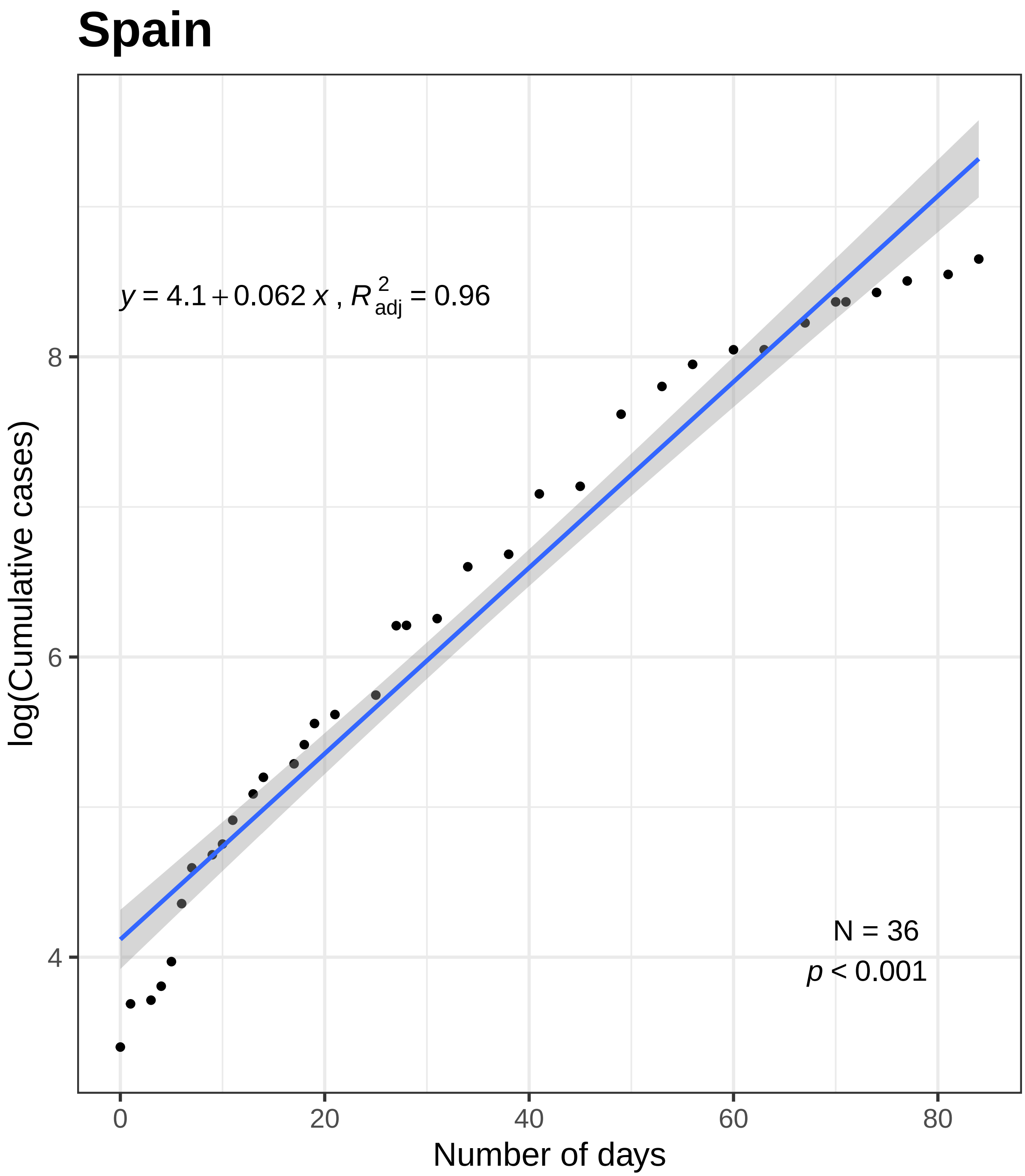
Portugal

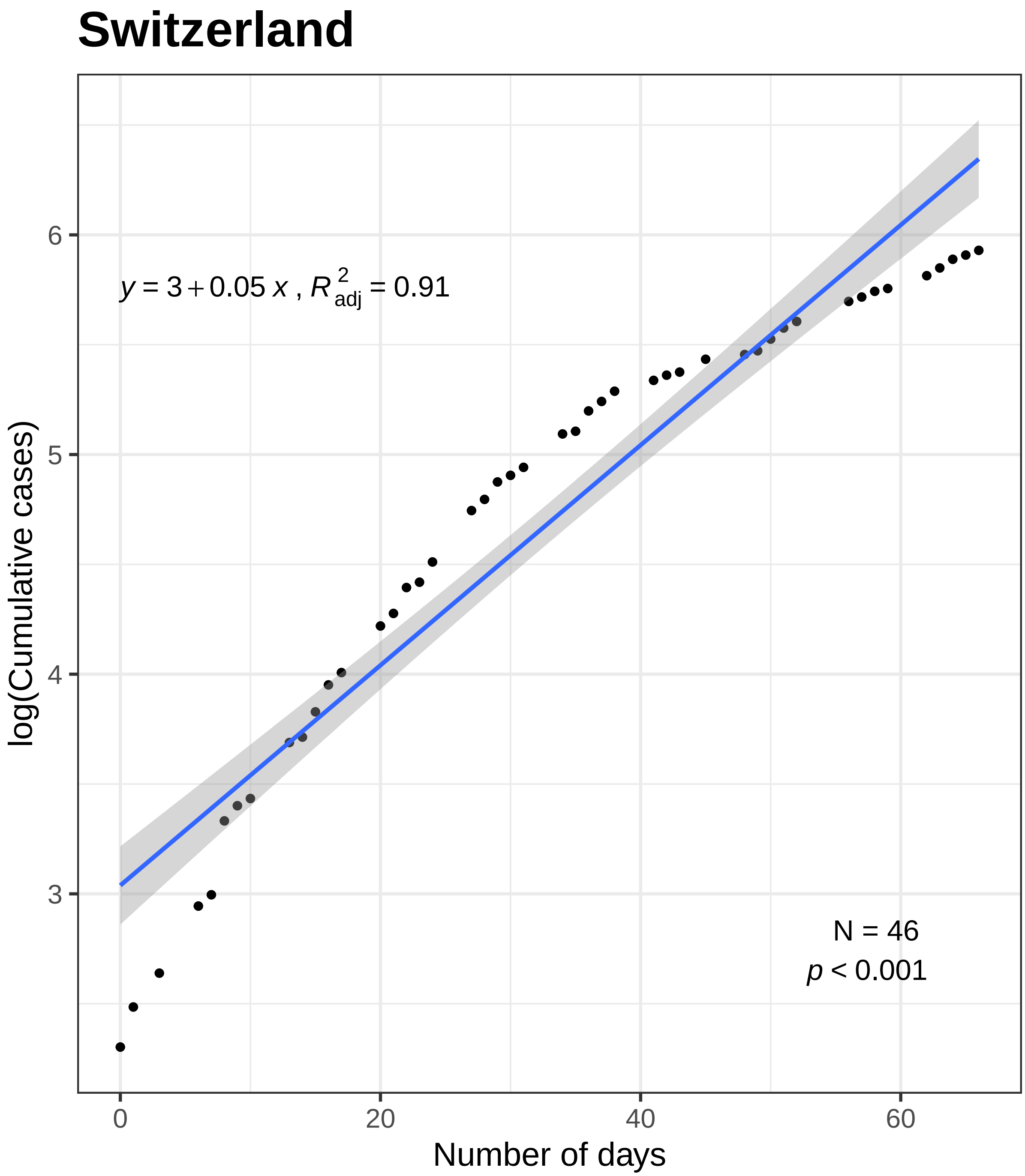


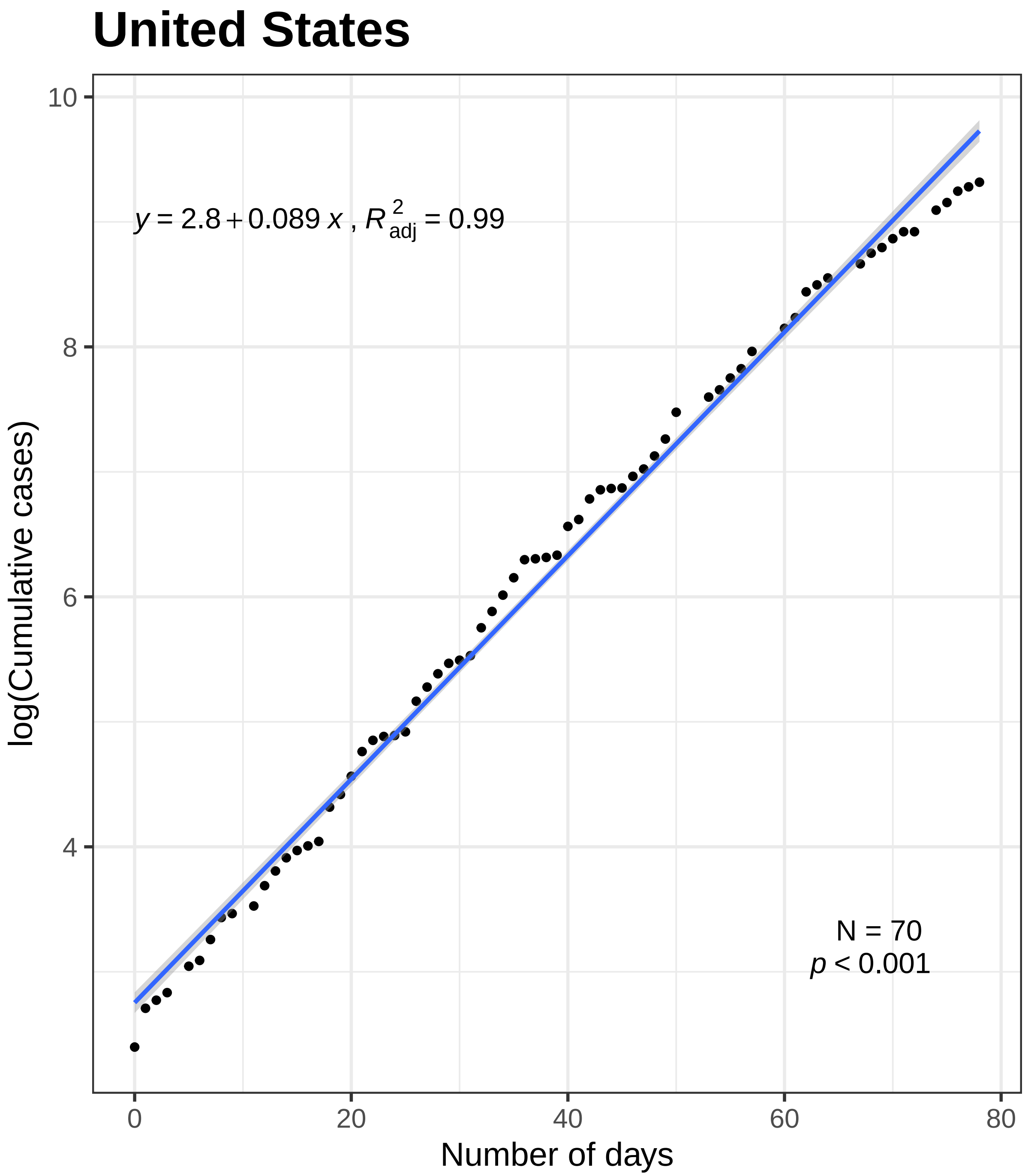
8
6
4
0
20
40
60
80
log(Cumulative cases)
Number of days
y = 4 + 0.042 x , R²adj = 0.8
N = 36
p < 0.001

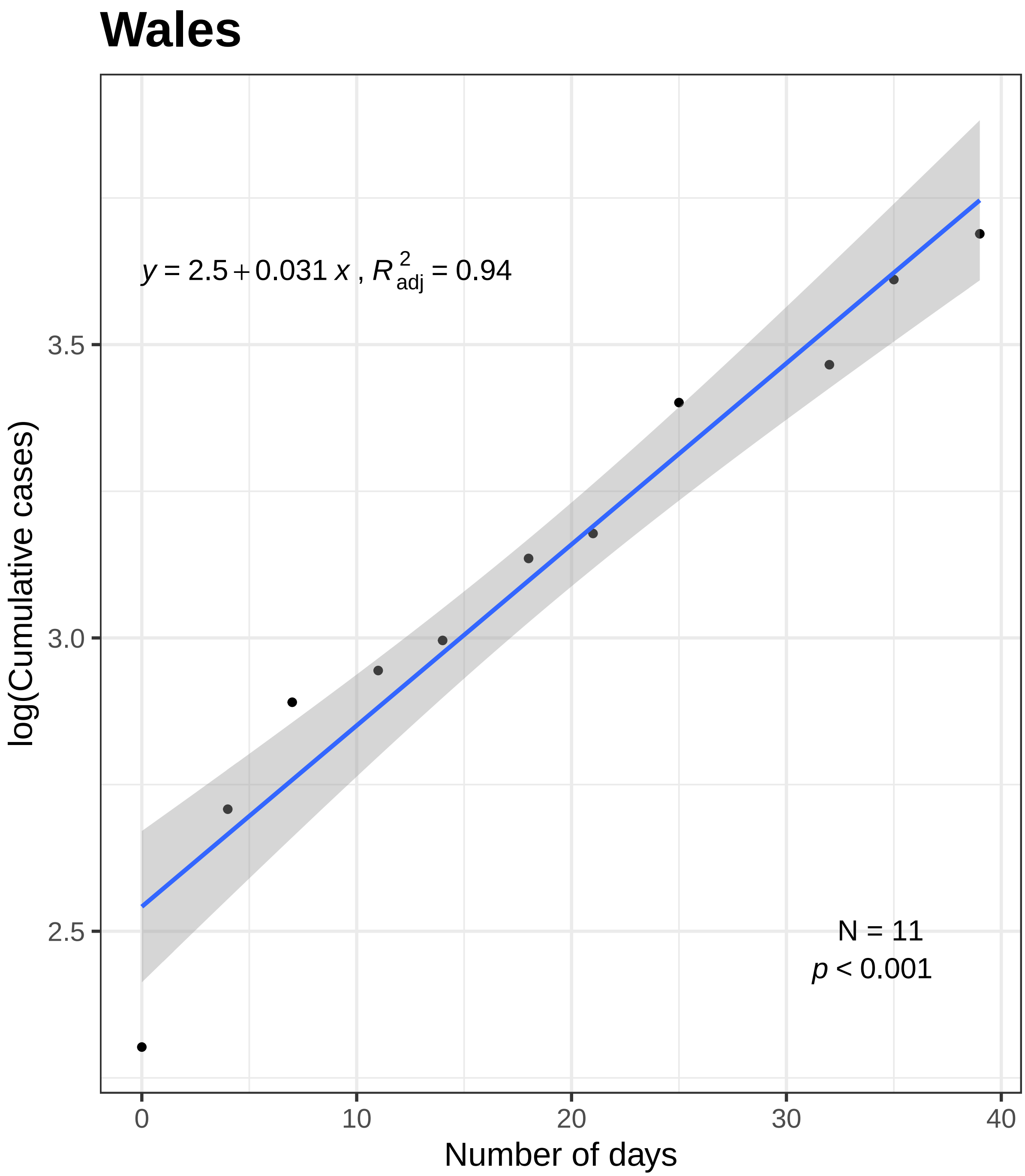


Scotland
y = 2.5 + 0.032 x , R 2 adj = 0.93
N = 20
p < 0.001
log(Cumulative cases)
Number of days
4
3
0
20
40
60


Spain
y = 4.1 + 0.062 x , R2adj = 0.96
N = 36
p < 0.001
log(Cumulative cases)
Number of days
8
6
4
0
20
40
60
80


Switzerland
$y = 3 + 0.05\,x$, $R^2_{adj} = 0.91$
N = 46
$p < 0.001$
log(Cumulative cases)
Number of days
6
5
4
3
0
20
40
60


United States
y = 2.8 + 0.089 x , R²adj = 0.99
N = 70
p < 0.001
log(Cumulative cases)
Number of days
10
8
6
4
0
20
40
60
80


Wales
$y = 2.5 + 0.031\,x$, $R^2_{adj} = 0.94$
N = 11
$p < 0.001$
log(Cumulative cases)
3.5
3.0
2.5
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	44	0.1039	0.0033	[0.0974 - 0.1103]	6.6735	[6.2836 - 7.1149]
Peru	28	0.0935	0.0034	[0.0868 - 0.1002]	7.4113	[6.9169 - 7.9818]
United States	70	0.0894	0.0009	[0.0876 - 0.0913]	7.7521	[7.5954 - 7.9154]
France	25	0.0659	0.0035	[0.0590 - 0.0727]	10.5237	[9.5286 - 11.7509]
Germany	64	0.0649	0.0031	[0.0588 - 0.0710]	10.6813	[9.7606 - 11.7937]
Spain	36	0.0619	0.0022	[0.0575 - 0.0663]	11.1933	[10.4497 - 12.0509]
Belgium	13	0.0544	0.0034	[0.0477 - 0.0611]	12.7484	[11.3477 - 14.5435]
Italy	29	0.0536	0.0024	[0.0489 - 0.0583]	12.9318	[11.8800 - 14.1878]
Netherlands	23	0.0532	0.0031	[0.0472 - 0.0593]	13.0265	[11.6975 - 14.6963]
England	31	0.0524	0.0036	[0.0453 - 0.0594]	13.2376	[11.6653 - 15.2998]
Switzerland	46	0.0501	0.0023	[0.0456 - 0.0546]	13.8330	[12.6948 - 15.1955]
Canada	44	0.0438	0.0019	[0.0400 - 0.0475]	15.8409	[14.5781 - 17.3433]
Portugal	36	0.0419	0.0035	[0.0350 - 0.0487]	16.5596	[14.2205 - 19.8199]
Scotland	20	0.0317	0.0020	[0.0278 - 0.0356]	21.8772	[19.4752 - 24.9550]
Wales	11	0.0309	0.0025	[0.0259 - 0.0359]	22.4469	[19.3307 - 26.7609]
Northern Ireland	8	0.0285	0.0030	[0.0226 - 0.0344]	24.3266	[20.1413 - 30.7074]

[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	0.104	3.663	2.179	6.031
Peru	0.094	3.219	2.017	5.043
United States	0.089	3.058	1.955	4.697
France	0.066	2.278	1.639	3.125
Germany	0.065	2.251	1.627	3.073
Spain	0.062	2.169	1.591	2.919
Belgium	0.054	1.973	1.503	2.562
Italy	0.054	1.954	1.495	2.528
Netherlands	0.053	1.945	1.490	2.511
England	0.052	1.924	1.481	2.474
Switzerland	0.050	1.871	1.456	2.379
Canada	0.044	1.728	1.388	2.132
Portugal	0.042	1.687	1.369	2.063
Scotland	0.032	1.486	1.268	1.730
Wales	0.031	1.471	1.261	1.706
Northern Ireland	0.028	1.428	1.238	1.637

[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 (2022W32), 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]	157	218,541,212	0.718
Asia				
Israel	2022-05-21	174	9,038,309	19.251
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	5,719	47,558,630	120.252
Portugal	2022-05-17	770	10,270,865	74.969
Luxembourg	2022-06-16	41	647,599	63.311
Netherlands	2022-05-20	1,025	17,564,014	58.358
Malta	2022-05-28	30	533,286	56.255
Belgium	2022-05-19	546	11,655,930	46.843
Switzerland	2022-05-21	376	8,740,472	43.018
England	2022-05-06	2,883	67,508,936	42.705
France	2022-05-19	2,659	64,626,628	41.144
Germany	2022-05-19	3,102	83,369,843	37.208
Iceland	2022-06-15	11	372,899	29.499
Denmark	2022-05-23	141	5,882,261	23.970
Austria	2022-05-23	198	8,939,617	22.149
Slovenia	2022-05-24	43	2,119,844	20.285
Ireland	2022-05-27	101	5,023,109	20.107
Norway	2022-05-31	70	5,434,319	12.881
Sweden	2022-05-19	126	10,549,347	11.944
Italy	2022-05-19	644	59,037,474	10.908
Hungary	2022-05-31	51	9,967,308	5.117
Greece	2022-06-08	48	10,384,971	4.622

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]
Finland	2022-05-27	22	5,540,745	3.971
Czech Republic	2022-05-24	35	10,493,986	3.335
Serbia	2022-06-17	23	7,221,365	3.185
Croatia	2022-06-23	12	4,030,358	2.977
Poland	2022-06-10	85	39,857,145	2.133
Slovakia	2022-07-07	10	5,643,453	1.772
Romania	2022-06-13	31	19,659,267	1.577
Scotland	2022-05-23	69	67,508,936	1.022
Wales	2022-05-26	40	67,508,936	0.593
Northern Ireland	2022-05-26	25	67,508,936	0.370
Latin America and the Caribbean				
Peru	2022-06-26	712	34,049,588	20.911
Puerto Rico	2022-06-29	50	3,252,407	15.373
Brazil	2022-06-08	2,848	215,313,498	13.227
Chile	2022-06-17	141	19,603,733	7.193
Mexico	2022-05-28	147	127,504,125	1.153
Argentina	2022-05-27	49	45,510,318	1.077
Colombia	2022-06-23	55	51,874,024	1.060
Bolivia	2022-08-01	11	12,224,110	0.900
Ecuador	2022-07-06	16	18,001,000	0.889
Northern America				
United States	2022-05-18	11,131	338,289,857	32.904
Canada	2022-05-19	1,059	38,454,327	27.539
Oceania				
Australia	2022-05-20	71	26,177,413	2.712

[1] Source: Global.health Monkeypox data repository

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

[3] As of complete epidemiological week #32 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	3	59,893,885	0.050
Morocco	2022-06-02	1	37,457,971	0.027
Sudan	2022-07-31	1	46,874,204	0.021
Asia				
Cyprus	2022-08-02	3	1,251,488	2.397
Qatar	2022-07-20	3	2,695,122	1.113
Lebanon	2022-06-20	6	5,489,739	1.093
Georgia	2022-06-15	1	3,744,385	0.267
Saudi Arabia	2022-07-14	5	36,408,820	0.137
Taiwan	2022-06-24	3	23,893,394	0.126
Turkey	2022-06-30	5	85,341,241	0.059
Thailand	2022-07-21	4	71,697,030	0.056
Japan	2022-07-25	4	123,951,692	0.032
South Korea	2022-06-22	1	51,815,810	0.019
Philippines	2022-07-28	1	115,559,009	0.009
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
Lithuania	2022-08-03	5	2,750,055	1.818
Latvia	2022-06-03	3	1,850,651	1.621
Montenegro	2022-08-01	1	627,082	1.595
Bosnia And Herzegovina	2022-07-13	3	3,233,526	0.928
Bulgaria	2022-06-23	4	6,781,953	0.590
Moldova	2022-08-08	1	3,272,996	0.306
Martinique	2022-07-15	2	64,626,628	0.031
Guadeloupe	2022-07-25	1	64,626,628	0.015
Russia	2022-07-12	1	144,713,314	0.007

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]
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	3	4,408,581	0.680
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	5	11,228,821	0.445
Honduras	2022-08-13	2	10,432,860	0.192
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 #32 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.