Contents

The research

COVID-19-related statistics is one of the most highligthed for last 1,5 years. That's why I've decided to took this topic for a research.

This research is based on open data.

The main source of data is World Health Organization.

Actual date at the momemt of research - 26 December 2021.

Table 1 – initial data for research[1]

Данные	**Источник**
Vaccination data	https://covid19.who.int/who-data/vaccination-data.csv
Daily cases and deaths data	https://covid19.who.int/WHO-COVID-19-global-data.csv
Actual cases and deaths data	https://covid19.who.int/WHO-COVID-19-global-table-data.csv
Human Development Index	https://ru.wikipedia.org/wiki/Список_стран_по_индексу_человеческого_развития
Population by countries	https://worldpopulationreview.com/countries

Looking through the files' content, I thought: what if overall country development level are heavily connected with metrics of COVID-related processes? So I've decided to add Human Development Index to the equation. On the moment of research it was the data for year 2019. HDI is based on metrics, which change slowly over time, so that's why a little outdate won't be critical.

Comparation of absolute data is incorrect - let me give Russia and Malta as examples. So I base my analysis on values per 100 000 population.

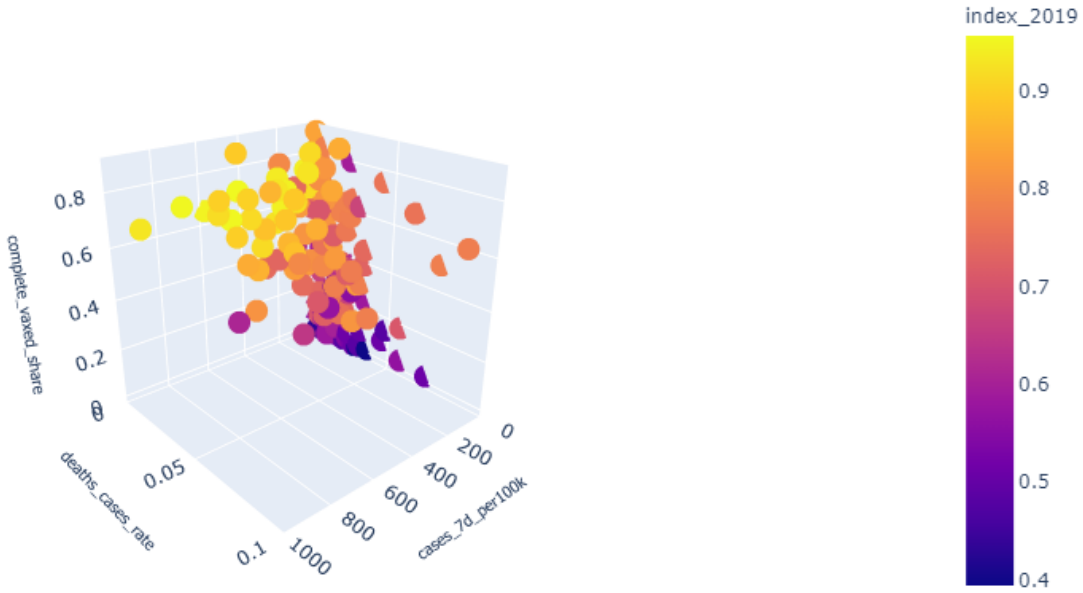
I delete countries with any absense of data. There are 57 such countries, but this is little island states in Caribbean or Pacific regions mosly.

Let's look at data distribution for some set of attributes. I choose new cases per 100k population, share of deaths in cases and share of completely vaccinated population.

I also add Human Development Index as fourth dimension - it is shown as color of object in 3D-graph.

[1] links leading to the actual dataset, not to the version used in the research

Figure 1 – distribution of countries by the selected features' values



In common case, in order to check dependencies between our parameters I need to build pairwise and partial correlation matrixes.

It seems I have some different groups of object, with unique dependencies in each.

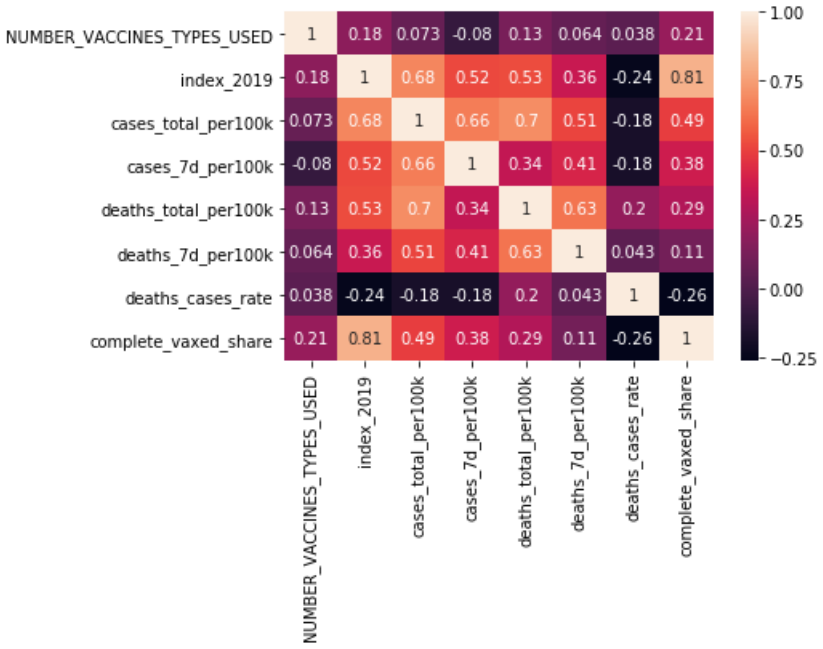
Most probably, I won't see significant correlations overall.

Before calculating correlations I need to check does parameters from our dataset have normal distribution. If distribution even for one parameter will be different from normal (null hypothesis can be rejected) - I cannot use parametric correlation coefficents.

Normal distribution tests for features is shown in Appendix 1.

I haven't normal distribution for any parameter, so I need to use non-parametrical correlations if I really want to check dependencies. Let's calculate parametrical correlations just to let it be.

Figure 2 – pairwise correlation matrix



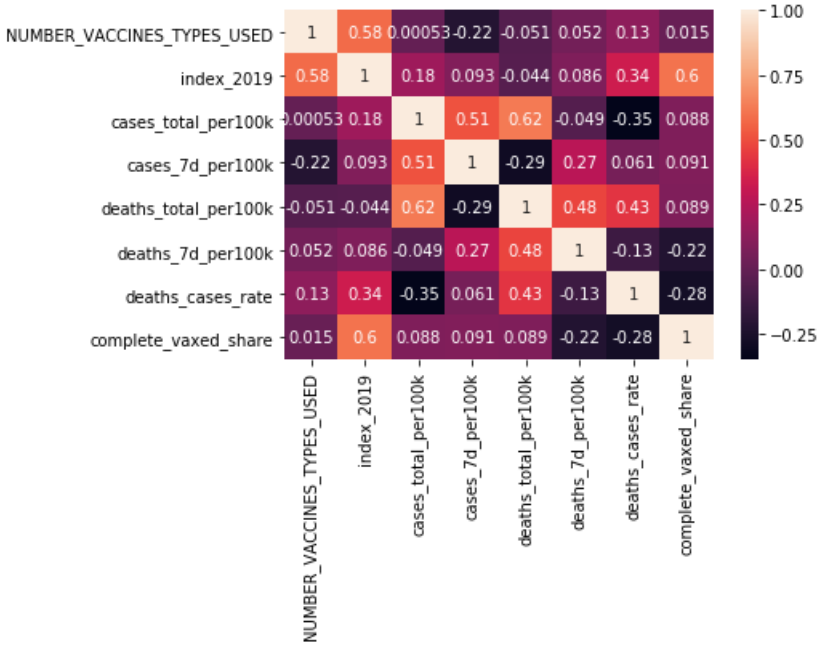
Please remember - parameters' distribution isn't normal, and that's why I cannot take this correlations seriously.

And even if I had normal distribution, a lot of significant correlations isn't a matter to celebrate.

Because pairwise correlation consists interconnections between all parameters of our dataset, I need to calculate strict correlations between two parameters, all other interconnections cleaned.

Partial correlations is created for this task.

Figure 3 – partial correlation matrix



Next step - gather together similar objects into homogeneous groups. It can be done via cluster analysis methods.

Looking into the group which this object belongs to, I can say how's COVID dynamic is going there.

Before implementing of cluster analysis methods I need to fit all parameters' values to the similar scales. In other case overall clusterization will be dependent from parameter with most absolute min-max difference. For example, if I will make a clusterization for two parameters "cases_7d_per100k" and "cases_total_per100k", first parameters won't have any influence on clusterization result.

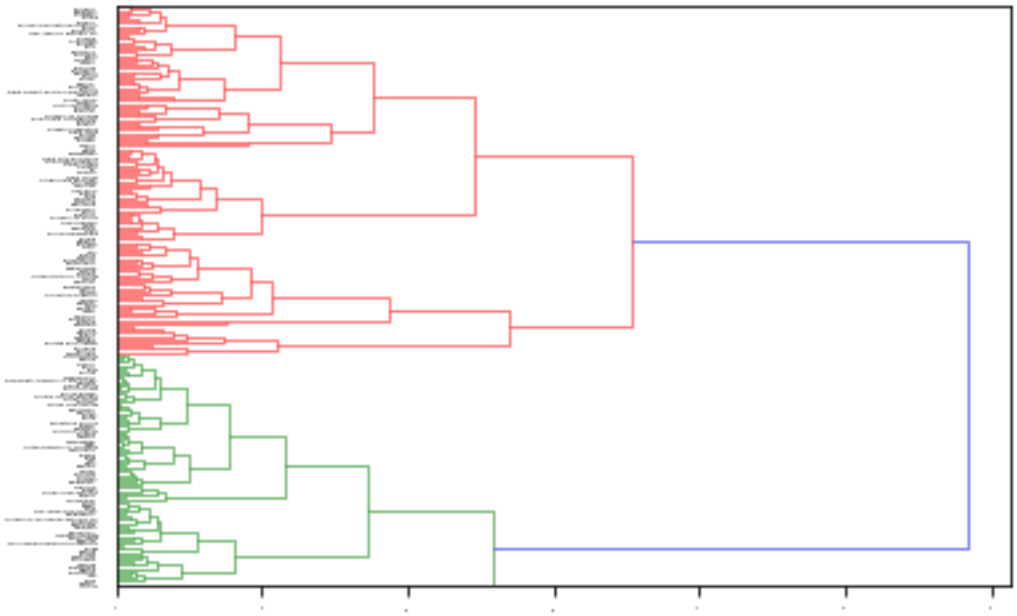
For this purpose I will use standardization procedure. This means that standardizated values of parameters in 99,7% cases will fit into [-3; +3] interval. Of course, if we talk about normal distributed parameter.

Number of available vaccines have no influence of COVID-related values. Let's drop it from further analysis.

Standardized features' values by country are shown in Appendix 2.

The most difficult in clusterization process - to understand how many groups will be optimal. It can be estimated via hierarchical cluster analysis procedures.

Figure 3 – dendrogram based on hierarchical cluster analysis result

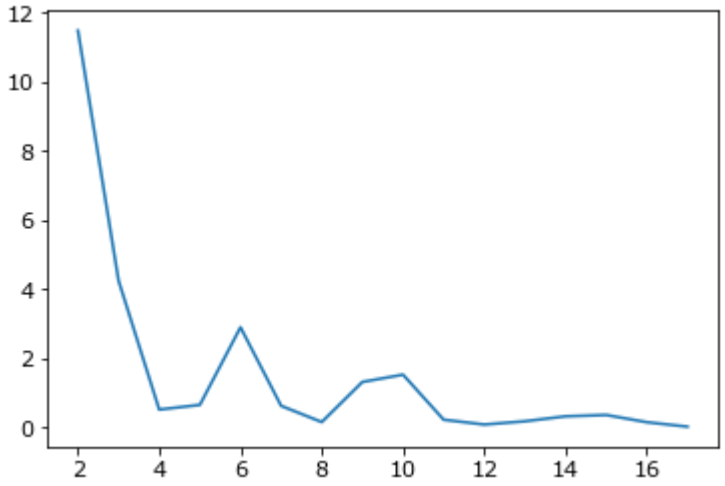


You can see output of this clusterization here:

https://github.com/Dimidro/COVID_research/blob/main/hier_covid_clust.png

Optimal number of classes is one, which returns the most distanced classes.

Figure 5 – distance between the next merged clusters as a function from current number of clusters



I can choose between 6, 9 and 10 groups. Let's choose 6, because I have the most distance between classes in this case.

Let's calculate clusters centers' coordinates of our dataset. This will help to describe classes and countries inside them.

Table 2 – clusters centers' coordinates by standardized features' values

cluster	index_ 2019	cases_ total_ per100k	cases_ 7d_ per100k	deaths_ total_ per100k	deaths_ 7d_ per100k	deaths_ cases_ rate	complete_ vaxed_ share
0	0,150	0,138	-0,352	1,238	0,087	1,336	-0,088
1	1,284	2,040	5,159	0,475	0,676	-0,618	1,203
2	0,438	-0,048	-0,290	-0,294	-0,279	-0,387	0,797
3	-1,031	-0,804	-0,458	-0,715	-0,475	0,053	-0,995
4	1,240	1,269	1,111	0,561	0,100	-0,425	0,966
5	0,780	1,285	0,772	1,820	2,908	0,226	0,078

Using standardized coordinates of clusters' centers, I can describe situation in this cluster relative to mean value worldwide and in comparison with each other.

Cluster 0 is distinguished by a high death rate for whole pandemic and the most share of dead in confirmed cases. Case rate per 100 000 capita is the lowest in comparison with other clusters. Mediocre countries by other parameters. I suppose insufficient capacity for timely diagnostic of COVID-19. It is very possible that a lot "COVID-19" cases were confirmed only post-mortem. I mean, countries in this cluster may have a large share of unaccounted COVID-19 cases, which leads to low amount of new cases for the last 7 days.

Cluster 1 has the highest human development index and incredible amount of cases in overall pandemic and for the last 7 days too. However, the deaths-to-cases rate is the lowest in comparison with all other clusters. Two possible reasons - mass COVID-19 testing and the highest rate of vaccinated population.

Cluster 2 has mediocre countries, which has slightly better COVID-situation than the world in average. Especially in new cases and new deaths for the last 7 days. I suppose, the reason is good percent of vaccinated population.

Cluster 3 can be named as "third world" countries. The lowest share of vaccinated population, the lowest deaths-to-cases rate. I suppose, whole "Sub-Saharan Africa" countries will be here. When all your life is the endless struggle for survival - you have much more significant troubles than COVID-19-related issues.

Cluster 4 is "First World" countries, which have high share of vaccinated population and very low deaths-to-cases rate. Two possible reasons - mass COVID-19 testing and the highest rate of vaccinated population. Difference with Cluster 1 is in significantly lower amount of cases and deaths for the last 7 days.

Cluster 5 has the most deaths as in overall pandemic and in the last 7 days. Share of vaccinated population is very low in comparison with the "First world" countries. Human development index is quiet high here, which let me suppose about presence of kind of acceptable healthcare services. Therefore, we can suppose sufficient capacity of COVID-19 testing. Together with low share of vaccinated population, it leads to devastating death rates.

To get meaningfully feature values, I will do a reverse operation to standardization - will multiply the values of the centers of the clusters by the standard deviations of the initial features and add the matching means to them.

Table 3 – clusters centers' coordinates by original features' values

cluster	index_ 2019	cases_ total_ per100k	cases_ 7d_ per100k	deaths_ total_ per100k	deaths_ 7d_ per100k	deaths_ cases_ rate	complete_ vaxed_ share
0	0,744	6 849	47,1	232,8	1,29	4,55%	38,2%
1	0,913	18 653	1274,2	149,4	2,54	0,80%	72,0%
2	0,787	5 695	60,8	65,6	0,51	1,24%	61,4%
3	0,567	1 003	23,5	19,5	0,09	2,09%	14,5%
4	0,907	13 865	372,9	158,9	1,32	1,17%	65,8%
5	0,838	13 965	297,3	296,3	7,29	2,42%	42,6%

The centers of the classes are obtained in the original values of the characteristics. It helps to show difference between classes more clear.

Next step - let's look through contains of each cluster.

Original features' values by country and assigned cluster are shown in Appendix 3.

Cluster 0 consists mostly from Latinoamerica countries with significant addition of ex-USSR countries. In general, objects are similar. Only Yemen (cluster 3 suits here better) and Ecuador with low cases and deaths for last 7 days standing out.

Cluster 1 – I wonder how Andorra hit the same cluster with UK and Denmark. COVID-situation in Andorra looks devastating. Especially with deaths. However, it's very possible that low population (<80 thousands) leads to such distortion.

Cluster 2 includes mostly small island/landlocked countries or strong administrative powers (Canada and New Zealand are exceptions). It is possible that good COVID-related statistics is backed by administrative measures, like mandatory vaccination or local lockdowns.

There are not only Sub-Saharan Africa in cluster 3, but also countries devastated by civil wars, like Libya or Iraq.

Cluster 4 consists mostly from European countries. The only exceptions - USA, Seychelles, Argentina and Israel.

Cluster 5 can be named "Antivaxxer Slavic brotherhood". Except few non-Slavic countries (Greece, Hungary, Lithuania) and Czech Republic, share is vaccinated population is low. Half countries from this cluster are also popular touristic destinations, which makes COVID-situation only worse. Russian Federation, to my great sorrow, is assigned to this cluster.

Conclusion

From this classification we cannot say that higher share of vaccinated population can decrease amount new cases of COVID-19. But one can see connections with amount of deaths: the more share of vaccinated - the less death-to-cases rate. It's possible that higher share of vaccinated also connected with human development index, but this should only convince us about the rightness of the "path of the vaccination".

Please, vaccinate if you're not already vaccinated. We can end this mess only after total vaccination and wearing masks in public places. After stabilization, we can return to our precious life with travels and open borders.

COVID-19 won't disappear. It will become a companion of humankind, like flu, measles and AIDS. However, if people will follow reasonable safety rules, take care about health - all will normalize. COVID will become no more than another seasonal illness.

About me

I’m Dmitry Evdokimov.

I don’t do Machine Learning as a part of my current job, but sometimes I apply it to interesting for me matters. I still remember something from my university courses, and it really helps me to make a deeper dive to data.

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- GitHub with source code: https://github.com/Dimidro/COVID_research
- Instagram: @dimidr0

Appendix 1 – normal distribution tests for features

In [13]:
```
from scipy import stats
k2, p = stats.normaltest(tot_data_short['index_2019'])
alpha = 0.05
print("p = {:g}".format(p))
if p < alpha:  # null hypothesis: x comes from a normal distribution
    print("The null hypothesis can be rejected")
else:
    print("The null hypothesis cannot be rejected")
```

```
p = 1.71708e-05
The null hypothesis can be rejected
```

In [14]:
```
k2, p = stats.normaltest(tot_data_short['cases_total_per100k'])
alpha = 0.05
print("p = {:g}".format(p))
if p < alpha:  # null hypothesis: x comes from a normal distribution
    print("The null hypothesis can be rejected")
else:
    print("The null hypothesis cannot be rejected")
```

```
p = 1.3366e-07
The null hypothesis can be rejected
```

In [15]:
```
k2, p = stats.normaltest(tot_data_short['cases_7d_per100k'])
alpha = 0.05
print("p = {:g}".format(p))
if p < alpha:  # null hypothesis: x comes from a normal distribution
    print("The null hypothesis can be rejected")
else:
    print("The null hypothesis cannot be rejected")
```

```
p = 7.98945e-34
The null hypothesis can be rejected
```

In [16]:
```
k2, p = stats.normaltest(tot_data_short['deaths_total_per100k'])
alpha = 0.05
print("p = {:g}".format(p))
if p < alpha:  # null hypothesis: x comes from a normal distribution
    print("The null hypothesis can be rejected")
else:
    print("The null hypothesis cannot be rejected")
```

```
p = 1.24756e-12
The null hypothesis can be rejected
```

In [17]:
```
k2, p = stats.normaltest(tot_data_short['deaths_7d_per100k'])
alpha = 0.05
print("p = {:g}".format(p))
if p < alpha:  # null hypothesis: x comes from a normal distribution
    print("The null hypothesis can be rejected")
else:
    print("The null hypothesis cannot be rejected")
```

```
p = 3.5563e-30
The null hypothesis can be rejected
```

In [18]:
```
k2, p = stats.normaltest(tot_data_short['deaths_cases_rate'])
alpha = 0.05
print("p = {:g}".format(p))
if p < alpha:  # null hypothesis: x comes from a normal distribution
    print("The null hypothesis can be rejected")
else:
    print("The null hypothesis cannot be rejected")
```

```
p = 3.37175e-49
The null hypothesis can be rejected
```

In [19]:

```
k2, p = stats.normaltest(tot_data_short['complete_vaxed_share'])
alpha = 0.05
print("p = {:g}".format(p))
if p < alpha:  # null hypothesis: x comes from a normal distribution
    print("The null hypothesis can be rejected")
else:
    print("The null hypothesis cannot be rejected")
```

```
p = 5.1142e-29
The null hypothesis can be rejected
```

Appendix 2 – standardized features' values by country

	Country_x	index_ 2019	cases_ total_ per100k	cases_ 7d_ per100k	deaths_ total_ per100k	deaths_ 7d_ per100k	deaths_ cases_ rate	complete_ vaxed_ share
0	United States of America	1,368	1,507	0,967	1,318	0,791	-0,214	0,729
1	India	-0,510	-0,564	-0,548	-0,579	-0,442	-0,316	-0,015
2	Brazil	0,292	0,708	-0,514	1,751	-0,304	0,414	0,961
3	The United Kingdom	1,408	1,786	3,632	1,088	0,020	-0,373	1,081
4	Russian Federation	0,686	0,174	0,012	0,997	1,816	0,486	0,117
5	Turkey	0,660	0,783	0,115	-0,022	0,178	-0,576	0,783
6	France	1,201	1,140	2,129	0,780	0,276	-0,305	1,237
7	Germany	1,509	0,364	0,792	0,304	0,908	-0,208	0,952
8	Iran (Islamic Republic of)	0,412	0,205	-0,485	0,519	-0,338	0,072	0,711
9	Spain	1,221	0,980	1,575	0,849	-0,271	-0,213	1,187
10	Italy	1,141	0,495	0,853	1,171	0,181	0,261	1,147
11	Argentina	0,827	0,944	-0,191	1,455	-0,388	0,093	1,092
12	Colombia	0,306	0,641	-0,449	1,421	-0,217	0,286	0,445
13	Indonesia	-0,022	-0,717	-0,561	-0,417	-0,508	0,725	-0,057
14	Poland	1,061	0,747	0,791	1,371	3,386	0,177	0,303
15	Mexico	0,386	-0,479	-0,533	1,203	-0,351	2,905	0,401
16	Ukraine	0,386	0,380	-0,127	1,091	1,505	0,317	-0,413
17	South Africa	-0,082	-0,066	0,349	0,488	-0,236	0,373	-0,556
18	Netherlands	1,489	1,863	1,915	0,204	0,379	-0,677	0,973
19	Philippines	-0,022	-0,554	-0,559	-0,474	-0,321	-0,099	-0,068
20	Malaysia	0,593	0,376	-0,220	-0,022	-0,186	-0,437	1,407
21	Czechia	1,194	2,693	1,798	2,146	1,892	-0,272	0,649
22	Peru	0,372	0,130	-0,417	4,662	0,095	3,606	0,800
23	Thailand	0,372	-0,458	-0,435	-0,613	-0,375	-0,524	0,882
24	Iraq	-0,316	-0,147	-0,539	-0,358	-0,430	-0,433	-1,037
25	Belgium	1,402	1,837	0,850	1,316	0,310	-0,311	1,193
26	Canada	1,388	-0,158	0,174	-0,170	-0,376	-0,212	1,377
27	Romania	0,713	0,551	-0,449	1,902	0,580	0,654	-0,380
28	Chile	0,867	0,540	-0,363	0,961	-0,096	0,095	1,713
29	Japan	1,321	-0,744	-0,559	-0,761	-0,516	-0,480	1,430
30	Viet Nam	-0,116	-0,705	0,027	-0,612	0,264	-0,042	0,794
31	Bangladesh	-0,597	-0,812	-0,559	-0,740	-0,515	-0,110	-0,454
32	Israel	1,321	1,527	-0,217	-0,036	-0,476	-0,717	1,018
33	Pakistan	-1,098	-0,873	-0,559	-0,777	-0,509	0,131	-0,519
34	Serbia	0,566	1,417	-0,155	0,421	0,632	-0,527	-0,150
35	Sweden	1,495	1,046	0,564	0,482	-0,431	-0,406	1,134
36	Austria	1,341	1,266	0,264	0,438	0,297	-0,486	0,893
37	Portugal	0,954	1,004	1,051	0,802	0,059	-0,244	1,208
38	Hungary	0,887	1,104	0,556	2,748	4,025	0,578	0,704
39	Switzerland	1,562	1,272	1,756	0,329	0,042	-0,532	0,854
40	Kazakhstan	0,693	-0,059	-0,484	-0,018	-0,341	-0,148	0,194
41	Greece	1,114	0,666	0,843	0,884	2,079	-0,035	0,786
42	Jordan	0,052	0,675	0,385	0,206	0,630	-0,419	-0,102
43	Cuba	0,412	0,407	-0,544	-0,221	-0,502	-0,583	1,627

44	Morocco	-0,236	-0,554	-0,543	-0,531	-0,495	-0,224	0,802
45	Georgia	0,606	2,754	1,404	2,165	3,864	-0,280	-0,606
46	Nepal	-0,797	-0,517	-0,541	-0,537	-0,497	-0,304	-0,295
47	Slovakia	0,927	1,453	1,519	1,830	3,864	-0,002	0,144
48	Bulgaria	0,633	0,740	0,072	3,139	2,972	1,130	-0,760
49	Tunisia	0,125	0,009	-0,501	1,062	-0,338	0,804	0,211
50	Lebanon	0,152	0,714	0,181	0,321	0,134	-0,370	-0,475
51	Belarus	0,680	0,208	-0,104	-0,367	0,029	-0,621	-0,243
52	Croatia	0,867	1,730	1,677	1,827	3,478	-0,109	0,237
53	Ireland	1,562	1,211	2,731	0,189	0,000	-0,577	1,203
54	Denmark	1,462	0,848	5,232	-0,403	0,096	-0,784	1,579
55	Guatemala	-0,390	-0,415	-0,523	-0,087	-0,442	0,307	-0,624
56	Azerbaijan	0,232	-0,001	-0,338	-0,156	-0,055	-0,332	0,131
57	Republic of Korea	1,301	-0,780	-0,162	-0,805	-0,064	-0,590	1,586
58	Sri Lanka	0,406	-0,530	-0,483	-0,263	-0,272	0,292	0,908
59	Bolivia (Plurinational State of)	-0,022	-0,191	-0,100	0,614	-0,022	0,748	-0,108
60	Costa Rica	0,593	0,818	-0,515	0,415	-0,428	-0,361	0,954
61	Saudi Arabia	0,887	-0,714	-0,551	-0,664	-0,506	-0,196	0,940
62	Ecuador	0,252	-0,481	-0,462	0,828	-0,377	2,215	1,046
63	Myanmar	-0,924	-0,810	-0,554	-0,573	-0,490	0,859	-0,641
64	Lithuania	1,074	2,077	1,152	1,566	2,348	-0,293	0,655
65	Panama	0,626	0,815	-0,288	0,654	-0,369	-0,237	0,887
66	Paraguay	0,045	0,072	-0,510	1,211	-0,050	0,823	-0,029
67	Slovenia	1,308	2,538	1,182	1,728	-0,112	-0,347	0,369
68	Venezuela (Bolivarian Republic of)	-0,069	-0,717	-0,521	-0,725	-0,442	-0,409	-0,003
69	Kuwait	0,566	0,577	-0,505	-0,372	-0,519	-0,722	1,286
70	Dominican Republic	0,232	-0,359	-0,509	-0,541	-0,506	-0,499	0,430
71	Uruguay	0,640	0,908	-0,273	0,724	-0,371	-0,242	1,378
72	Mongolia	0,105	0,909	-0,415	-0,351	-0,434	-0,767	0,931
73	Libya	0,018	-0,078	-0,329	-0,154	-0,181	-0,269	-1,111
74	Ethiopia	-1,579	-0,913	-0,531	-0,841	-0,505	-0,096	-1,424
75	Honduras	-0,583	-0,359	-0,549	0,055	-0,496	0,399	-0,113
76	Egypt	-0,096	-0,907	-0,537	-0,705	-0,385	1,925	-0,832
77	Republic of Moldova	0,192	0,530	-0,293	1,282	0,918	0,299	-0,927
78	Norway	1,575	0,094	1,392	-0,684	-0,046	-0,850	1,180
79	Armenia	0,366	0,903	-0,417	1,555	0,463	0,167	-0,804
80	Oman	0,613	-0,025	-0,548	-0,173	-0,519	-0,331	0,567
81	Bosnia and Herzegovina	0,392	0,448	-0,128	2,818	1,786	1,369	-0,705
82	Bahrain	0,874	1,605	-0,391	-0,164	-0,519	-0,772	1,014
83	Singapore	1,448	-0,209	-0,403	-0,767	-0,431	-0,878	1,527
84	Kenya	-0,804	-0,886	-0,455	-0,805	-0,515	-0,004	-1,291
85	Latvia	0,967	1,358	0,681	1,303	1,219	-0,167	0,367
86	Australia	1,489	-0,800	-0,052	-0,817	-0,437	-0,607	1,347
87	Estonia	1,141	1,891	0,942	0,419	0,545	-0,612	0,526
88	Nigeria	-1,218	-0,948	-0,539	-0,881	-0,517	-0,360	-1,473
89	Finland	1,448	-0,306	0,580	-0,646	-0,426	-0,688	1,283
90	North Macedonia	0,352	0,753	-0,155	2,560	1,129	0,806	-0,060
91	Zambia	-0,918	-0,777	-0,336	-0,716	-0,484	-0,168	-1,423

92	Algeria	0,179	-0,888	-0,544	-0,767	-0,477	0,465	-1,074
93	Albania	0,493	0,193	-0,253	0,120	-0,061	-0,232	-0,209
94	Botswana	0,092	0,410	0,758	0,032	-0,499	-0,416	0,069
95	Zimbabwe	-1,004	-0,753	-0,047	-0,601	-0,304	0,227	-0,786
96	Uzbekistan	-0,009	-0,872	-0,547	-0,855	-0,489	-0,645	-0,299
97	Kyrgyzstan	-0,162	-0,517	-0,546	-0,509	-0,441	-0,246	-1,017
98	Mozambique	-1,773	-0,883	-0,433	-0,838	-0,499	-0,414	-0,907
99	Montenegro	0,720	3,182	0,463	2,589	0,978	-0,264	-0,117
100	Afghanistan	-1,406	-0,902	-0,562	-0,725	-0,507	1,386	-1,192
101	Namibia	-0,503	-0,091	0,652	0,377	-0,319	0,297	-1,055
102	Ghana	-0,737	-0,898	-0,533	-0,858	-0,498	-0,540	-1,269
103	Uganda	-1,185	-0,921	-0,546	-0,831	-0,516	0,276	-1,436
104	China	0,265	-0,964	-0,563	-0,891	-0,519	1,245	1,336
105	El Salvador	-0,323	-0,665	-0,539	-0,359	-0,432	0,597	0,868
106	Cambodia	-0,851	-0,851	-0,563	-0,732	-0,489	0,266	1,517
107	Cameroon	-1,058	-0,901	-0,551	-0,832	-0,493	-0,145	-1,462
108	Rwanda	-1,192	-0,841	-0,502	-0,801	-0,515	-0,351	-0,019
109	Lao People's Democratic Republic	-0,724	-0,743	-0,028	-0,859	-0,315	-0,885	0,056
110	Luxembourg	1,301	1,518	1,301	0,413	0,222	-0,550	0,790
111	Maldives	0,125	1,830	-0,010	-0,456	-0,433	-0,888	1,028
112	Jamaica	0,085	-0,466	-0,510	-0,139	-0,234	0,349	-0,847
113	Trinidad and Tobago	0,499	0,029	0,953	0,829	5,679	0,552	0,243
114	Senegal	-1,399	-0,896	-0,560	-0,794	-0,508	0,292	-1,340
115	Democratic Republic of the Congo	-1,613	-0,953	-0,531	-0,883	-0,519	-0,196	-1,546
116	Malawi	-1,593	-0,910	-0,464	-0,786	-0,502	0,758	-1,422
117	Mauritius	0,553	-0,119	-0,288	-0,346	0,478	-0,440	1,180
118	Angola	-0,938	-0,934	-0,559	-0,847	-0,518	0,338	-1,118
119	Eswatini	-0,737	-0,101	1,999	0,096	0,002	0,015	-0,573
120	Côte d'Ivoire	-1,225	-0,928	-0,553	-0,870	-0,519	-0,445	-1,337
121	Fiji	0,145	-0,025	-0,513	-0,187	-0,519	-0,344	1,015
122	Suriname	0,112	0,437	-0,405	0,942	0,037	0,165	-0,094
123	Syrian Arab Republic	-1,031	-0,922	-0,553	-0,751	-0,439	1,946	-1,388
124	Madagascar	-1,292	-0,939	-0,540	-0,862	-0,493	0,063	-1,477
125	Sudan	-1,412	-0,949	-0,560	-0,827	-0,516	2,687	-1,443
126	Malta	1,161	0,602	1,648	0,084	-0,307	-0,461	1,819
127	Mauritania	-1,172	-0,830	-0,534	-0,729	-0,450	0,078	-0,973
128	Guyana	-0,263	-0,172	-0,389	0,310	0,373	0,356	-0,155
129	Cabo Verde	-0,376	0,143	-0,461	-0,320	-0,435	-0,558	0,192
130	Gabon	-0,122	-0,697	-0,493	-0,779	-0,498	-0,641	-1,228
131	Papua New Guinea	-1,111	-0,902	-0,560	-0,835	-0,509	-0,183	-1,460
132	Belize	-0,035	0,281	-0,375	0,443	0,062	-0,051	0,322
133	Guinea	-1,633	-0,929	-0,561	-0,868	-0,516	-0,377	-1,284
134	Barbados	0,620	0,564	-0,003	-0,079	-0,029	-0,544	0,323
135	Togo	-1,379	-0,914	-0,530	-0,868	-0,508	-0,560	-1,131
136	United Republic of Tanzania	-1,285	-0,959	-0,564	-0,883	-0,519	0,409	-1,483
137	Lesotho	-1,299	-0,772	-0,127	-0,612	-0,519	0,298	-0,415
138	Haiti	-1,412	-0,929	-0,562	-0,834	-0,519	0,501	-1,527
139	Benin	-1,178	-0,933	-0,563	-0,882	-0,519	-0,696	-1,181

140	Seychelles	0,499	2,985	0,472	0,273	-0,519	-0,762	1,475
141	Burundi	-1,927	-0,935	-0,482	-0,893	-0,519	-1,001	-1,549
142	Bahamas	0,620	-0,022	-0,259	0,751	-0,519	0,563	-0,145
143	Iceland	1,522	0,071	2,084	-0,796	-0,382	-0,945	0,980
144	Andorra	0,981	3,487	6,612	0,740	1,912	-0,696	0,949
145	Timor-Leste	-0,771	-0,728	-0,563	-0,811	-0,519	-0,712	-0,033
146	Mali	-1,920	-0,951	-0,549	-0,866	-0,487	0,691	-1,481
147	Congo	-0,984	-0,910	-0,539	-0,835	-0,502	-0,053	-1,162
148	Tajikistan	-0,356	-0,937	-0,564	-0,883	-0,519	-0,660	-0,465
149	Burkina Faso	-1,800	-0,953	-0,556	-0,881	-0,473	-0,065	-1,434
150	Brunei Darussalam	0,780	-0,403	-0,509	-0,776	-0,519	-0,840	1,857
151	South Sudan	-1,927	-0,945	-0,515	-0,883	-0,511	-0,540	-1,489
152	Equatorial Guinea	-0,864	-0,814	-0,563	-0,784	-0,519	-0,364	-1,014
153	Djibouti	-1,319	-0,748	-0,555	-0,721	-0,519	-0,306	-1,295
154	Nicaragua	-0,410	-0,933	-0,561	-0,865	-0,512	-0,202	-0,021
155	New Zealand	1,402	-0,922	-0,526	-0,885	-0,509	-0,840	1,427
156	Saint Lucia	0,252	0,189	-0,310	0,571	2,541	0,129	-0,550
157	Central African Republic	-2,167	-0,927	-0,564	-0,875	-0,519	-0,593	-1,281
158	Yemen	-1,680	-0,960	-0,563	-0,835	-0,507	9,160	-1,504
159	Gambia	-1,506	-0,900	-0,556	-0,768	-0,519	0,731	-1,196
160	Niger	-2,187	-0,961	-0,562	-0,884	-0,513	0,929	-1,479
161	Sierra Leone	-1,800	-0,953	-0,556	-0,881	-0,519	-0,075	-1,369
162	Dominica	0,138	0,490	0,893	-0,336	0,784	-0,681	-0,099
163	Guinea-Bissau	-1,613	-0,914	-0,562	-0,827	-0,519	0,168	-1,507
164	Grenada	0,386	-0,120	-0,492	0,727	-0,519	0,720	-0,363
165	Liberia	-1,613	-0,947	-0,556	-0,843	-0,519	1,484	-0,992
166	Liechtenstein	1,321	1,518	2,078	0,710	-0,519	-0,441	1,001
167	Saint Vincent and the Grenadines	0,112	-0,124	-0,212	-0,244	0,326	-0,325	-0,682
168	Chad	-2,161	-0,960	-0,564	-0,884	-0,519	0,618	-1,532
169	Comoros	-1,118	-0,876	-0,374	-0,738	-0,413	0,564	-0,496
170	Antigua and Barbuda	0,379	-0,279	-0,436	0,191	-0,519	0,415	0,692
171	Sao Tome and Principe	-0,644	-0,696	-0,556	-0,660	-0,519	-0,239	-0,673
172	Saint Kitts and Nevis	0,386	-0,120	-0,463	-0,415	-0,519	-0,514	0,261
173	Bhutan	-0,450	-0,911	-0,560	-0,891	-0,519	-0,973	1,221
174	Solomon Islands	-1,031	-0,965	-0,564	-0,894	-0,519	-1,032	-1,220
175	Palau	0,700	-0,959	-0,564	-0,894	-0,519	-1,032	1,765
176	Vanuatu	-0,751	-0,965	-0,564	-0,894	-0,519	-1,032	-0,937
177	Marshall Islands	-0,116	-0,965	-0,564	-0,894	-0,519	-1,032	-0,111
178	Samoa	-0,042	-0,966	-0,564	-0,894	-0,519	-1,032	0,795
179	Tonga	0,025	-0,966	-0,564	-0,894	-0,519	-1,032	0,590

Appendix 3 – the distribution of countries by clusters and the initial feature values at the time of the study

	Кластер	Country_x	index_ 2019	cases_ total_ per100k	cases_ 7d_ per100k	deaths_ total_ per100k	deaths_ 7d_ per100k	deaths_ cases_ rate	complete_ vaxed_ share
0	0	Armenia	0,776	11 594	32,65	267,37	2,089	2,31%	19,5%
1	0	Bahamas	0,814	5 855	67,77	179,64	0,000	3,07%	36,7%
2	0	Bolivia (Plurinational State of)	0,718	4 808	103,12	164,63	1,056	3,42%	37,7%
3	0	Brazil	0,765	10 383	11,08	288,77	0,457	2,78%	65,7%
4	0	Colombia	0,767	9 969	25,57	252,67	0,642	2,53%	52,2%
5	0	Ecuador	0,759	3 009	22,60	187,96	0,302	6,25%	67,9%
6	0	Grenada	0,779	5 249	15,93	176,96	0,000	3,37%	31,0%
7	0	Guyana	0,682	4 925	38,97	131,46	1,898	2,67%	36,5%
8	0	Mexico	0,779	3 022	6,75	228,89	0,357	7,57%	51,0%
9	0	North Macedonia	0,774	10 663	91,04	377,07	3,505	3,54%	39,0%
10	0	Paraguay	0,728	6 438	12,01	229,76	0,997	3,57%	39,8%
11	0	Peru	0,777	6 798	32,73	606,54	1,307	8,92%	61,4%
12	0	Republic of Moldova	0,75	9 279	60,19	237,50	3,057	2,56%	16,3%
13	0	Romania	0,828	9 412	25,55	305,22	2,337	3,24%	30,6%
14	0	South Africa	0,709	5 585	203,32	150,87	0,601	2,70%	26,0%
15	0	Suriname	0,738	8 702	35,32	200,41	1,183	2,30%	38,1%
16	0	Tunisia	0,74	6 047	13,86	213,57	0,385	3,53%	46,0%
17	0	Ukraine	0,779	8 352	97,19	216,68	4,304	2,59%	29,7%
18	0	Yemen	0,47	33	0,07	6,50	0,026	19,61%	1,2%
19	1	Andorra	0,868	27 628	1 597,83	178,40	5,171	0,65%	65,3%
20	1	Denmark	0,94	11 255	1 290,58	53,58	1,307	0,48%	81,8%
21	1	The United Kingdom	0,932	17 077	934,19	216,36	1,147	1,27%	68,8%
22	2	Albania	0,795	7 192	69,23	110,69	0,975	1,54%	35,1%
23	2	Antigua and Barbuda	0,778	4 259	28,36	118,50	0,000	2,78%	58,6%
24	2	Australia	0,944	1 027	113,89	8,38	0,174	0,82%	75,8%
25	2	Azerbaijan	0,756	5 988	50,17	80,58	0,988	1,35%	44,0%
26	2	Bahrain	0,852	15 951	38,49	79,73	0,000	0,50%	67,0%
27	2	Barbados	0,814	9 491	124,78	88,98	1,043	0,94%	49,0%
28	2	Belarus	0,823	7 285	102,42	57,52	1,165	0,79%	34,2%
29	2	Belize	0,716	7 735	41,98	145,96	1,235	1,89%	48,9%
30	2	Bhutan	0,654	341	0,90	0,38	0,000	0,11%	72,5%
31	2	Botswana	0,735	8 539	294,38	101,16	0,042	1,18%	42,3%
32	2	Brunei Darussalam	0,838	3 494	12,23	12,91	0,000	0,37%	89,1%
33	2	Cabo Verde	0,665	6 879	22,78	62,64	0,178	0,91%	45,6%
34	2	Cambodia	0,594	711	0,24	17,74	0,065	2,50%	80,2%
35	2	Canada	0,929	5 011	164,22	79,03	0,305	1,58%	76,5%
36	2	Chile	0,851	9 342	44,59	202,47	0,900	2,17%	85,3%
37	2	China	0,761	9	0,05	0,39	0,000	4,38%	75,5%
38	2	Costa Rica	0,81	11 069	10,80	142,89	0,195	1,29%	65,5%
39	2	Cuba	0,783	8 521	4,45	73,49	0,035	0,86%	83,1%

40	2	Dominica	0,742	9 035	324,25	60,97	2,771	0,67%	37,9%
41	2	Dominican Republic	0,756	3 764	12,21	38,55	0,027	1,02%	51,8%
42	2	El Salvador	0,673	1 866	5,46	58,48	0,184	3,13%	63,2%
43	2	Fiji	0,743	5 837	11,30	77,20	0,000	1,32%	67,1%
44	2	Finland	0,938	4 094	254,74	27,11	0,198	0,66%	74,1%
45	2	Iran (Islamic Republic of)	0,783	7 266	17,56	154,31	0,386	2,12%	59,1%
46	2	Japan	0,919	1 373	1,11	14,58	0,006	1,06%	77,9%
47	2	Jordan	0,729	10 183	211,14	120,06	2,444	1,18%	37,8%
48	2	Kazakhstan	0,825	5 624	17,75	95,60	0,379	1,70%	45,6%
49	2	Kuwait	0,806	9 574	13,08	56,97	0,000	0,60%	74,2%
50	2	Lebanon	0,744	10 422	165,77	132,66	1,389	1,27%	28,1%
51	2	Malaysia	0,81	8 324	76,47	95,26	0,708	1,14%	77,3%
52	2	Maldives	0,74	17 347	123,25	47,83	0,184	0,28%	67,4%
53	2	Mauritius	0,804	5 256	61,41	59,84	2,120	1,14%	71,4%
54	2	Mongolia	0,737	11 631	32,98	59,29	0,180	0,51%	64,9%
55	2	Morocco	0,686	2 554	4,66	39,68	0,051	1,55%	61,5%
56	2	New Zealand	0,931	273	8,44	1,01	0,021	0,37%	77,9%
57	2	Oman	0,813	5 838	3,39	78,74	0,000	1,35%	55,3%
58	2	Palau	0,826	44	0,00	0,00	0,000	0,00%	86,7%
59	2	Panama	0,815	11 049	61,32	169,00	0,320	1,53%	63,7%
60	2	Philippines	0,718	2 555	0,95	45,85	0,421	1,79%	38,7%
61	2	Republic of Korea	0,916	1 150	89,39	9,77	0,969	0,85%	82,0%
62	2	Saint Kitts and Nevis	0,779	5 246	22,41	52,29	0,000	1,00%	47,4%
63	2	Saint Vincent and the Grenadines	0,738	5 222	78,19	71,00	1,798	1,36%	22,7%
64	2	Samoa	0,715	1	0,00	0,00	0,000	0,00%	61,3%
65	2	Saudi Arabia	0,854	1 560	2,84	25,09	0,028	1,61%	65,1%
66	2	Singapore	0,938	4 693	35,66	13,87	0,187	0,30%	80,5%
67	2	Sri Lanka	0,782	2 705	18,01	68,90	0,526	2,55%	64,3%
68	2	Thailand	0,777	3 148	28,65	30,74	0,307	0,98%	63,6%
69	2	Tonga	0,725	1	0,00	0,00	0,000	0,00%	56,0%
70	2	Turkey	0,82	10 852	151,11	95,20	1,483	0,88%	61,0%
71	2	Uruguay	0,817	11 628	64,79	176,66	0,316	1,52%	76,6%
72	2	Venezuela (Bolivarian Republic of)	0,711	1 540	9,52	18,46	0,164	1,20%	40,4%
73	2	Viet Nam	0,704	1 618	131,57	30,82	1,665	1,90%	61,3%
74	3	Afghanistan	0,511	396	0,44	18,43	0,025	4,65%	9,4%
75	3	Algeria	0,748	483	4,25	13,91	0,090	2,88%	12,4%
76	3	Angola	0,581	194	1,10	5,12	0,003	2,64%	11,3%
77	3	Bangladesh	0,632	951	1,09	16,87	0,008	1,77%	28,6%
78	3	Benin	0,545	200	0,22	1,29	0,000	0,65%	9,6%
79	3	Burkina Faso	0,452	79	1,71	1,47	0,098	1,86%	3,0%
80	3	Burundi	0,433	193	18,24	0,11	0,000	0,06%	0,0%
81	3	Cameroon	0,563	398	2,90	6,80	0,055	1,71%	2,3%
82	3	Central African Republic	0,397	243	0,00	2,05	0,000	0,84%	7,0%
83	3	Chad	0,398	34	0,00	1,07	0,000	3,17%	0,5%
84	3	Comoros	0,554	557	42,32	17,11	0,225	3,07%	27,5%
85	3	Congo	0,574	345	5,50	6,49	0,035	1,88%	10,1%

86	3	Côte d'Ivoire	0,538	231	2,37	2,61	0,000	1,13%	5,6%
87	3	Democratic Republic of the Congo	0,48	76	7,22	1,22	0,000	1,61%	0,1%
88	3	Djibouti	0,524	1 352	2,00	18,86	0,000	1,40%	6,7%
89	3	Egypt	0,707	363	6,01	20,62	0,285	5,69%	18,8%
90	3	Equatorial Guinea	0,592	939	0,07	12,07	0,000	1,29%	14,0%
91	3	Eswatini	0,611	5 364	570,64	108,07	1,109	2,01%	25,6%
92	3	Ethiopia	0,485	324	7,22	5,84	0,029	1,80%	3,3%
93	3	Gabon	0,703	1 669	15,71	12,55	0,044	0,75%	8,4%
94	3	Gambia	0,496	406	1,69	13,75	0,000	3,39%	9,3%
95	3	Ghana	0,611	422	6,91	3,99	0,044	0,95%	7,4%
96	3	Guatemala	0,663	3 420	9,02	88,12	0,164	2,58%	24,2%
97	3	Guinea	0,477	229	0,55	2,88	0,007	1,26%	7,0%
98	3	Guinea-Bissau	0,48	320	0,30	7,39	0,000	2,31%	1,1%
99	3	Haiti	0,51	225	0,33	6,63	0,000	2,95%	0,6%
100	3	Honduras	0,634	3 766	3,19	103,64	0,050	2,75%	37,6%
101	3	India	0,645	2 495	3,40	34,36	0,164	1,38%	40,1%
102	3	Indonesia	0,718	1 542	0,49	52,12	0,023	3,38%	39,0%
103	3	Iraq	0,674	5 079	5,50	58,51	0,189	1,15%	13,4%
104	3	Jamaica	0,734	3 102	12,04	82,40	0,605	2,66%	18,4%
105	3	Kenya	0,601	493	24,16	9,74	0,009	1,98%	6,8%
106	3	Kyrgyzstan	0,697	2 781	3,95	42,06	0,166	1,51%	13,9%
107	3	Lao People's Democratic Republic	0,613	1 380	119,31	3,90	0,434	0,28%	42,0%
108	3	Lesotho	0,527	1 204	97,31	30,80	0,000	2,56%	29,7%
109	3	Liberia	0,48	114	1,64	5,54	0,000	4,84%	14,6%
110	3	Libya	0,724	5 510	52,15	80,85	0,719	1,47%	11,5%
111	3	Madagascar	0,528	166	5,28	3,50	0,056	2,11%	1,9%
112	3	Malawi	0,483	342	22,11	11,79	0,036	3,44%	3,3%
113	3	Mali	0,434	94	3,35	3,11	0,067	3,31%	1,8%
114	3	Marshall Islands	0,704	7	0,00	0,00	0,000	0,00%	37,6%
115	3	Mauritania	0,546	843	6,60	17,99	0,147	2,13%	15,1%
116	3	Mozambique	0,456	513	29,12	6,09	0,044	1,19%	16,8%
117	3	Myanmar	0,583	965	2,05	35,10	0,062	3,64%	23,8%
118	3	Namibia	0,646	5 428	270,74	138,71	0,425	2,56%	12,9%
119	3	Nepal	0,602	2 786	5,01	39,03	0,047	1,40%	32,8%
120	3	Nicaragua	0,66	202	0,57	3,22	0,015	1,60%	40,0%
121	3	Niger	0,394	29	0,24	1,09	0,012	3,77%	1,8%
122	3	Nigeria	0,539	109	5,39	1,41	0,004	1,29%	2,0%
123	3	Pakistan	0,557	574	0,95	12,83	0,022	2,24%	27,0%
124	3	Papua New Guinea	0,555	395	0,72	6,46	0,022	1,63%	2,4%
125	3	Rwanda	0,543	774	13,63	10,13	0,008	1,31%	40,0%
126	3	Sao Tome and Principe	0,625	1 673	1,79	25,52	0,000	1,53%	22,9%
127	3	Senegal	0,512	432	0,69	10,99	0,023	2,55%	5,5%
128	3	Sierra Leone	0,452	81	1,71	1,49	0,000	1,84%	4,7%
129	3	Solomon Islands	0,567	3	0,00	0,00	0,000	0,00%	8,6%
130	3	South Sudan	0,433	125	10,77	1,19	0,018	0,95%	1,6%
131	3	Sudan	0,51	103	0,86	7,34	0,007	7,15%	2,8%

132	3	Syrian Arab Republic	0,567	273	2,29	15,64	0,170	5,73%	4,2%
133	3	Tajikistan	0,668	179	0,00	1,28	0,000	0,71%	28,4%
134	3	Timor-Leste	0,606	1 476	0,22	9,08	0,000	0,62%	39,7%
135	3	Togo	0,515	320	7,57	2,90	0,024	0,91%	10,9%
136	3	Uganda	0,544	276	3,84	6,95	0,006	2,52%	3,0%
137	3	United Republic of Tanzania	0,529	43	0,00	1,19	0,000	2,77%	1,8%
138	3	Uzbekistan	0,72	583	3,63	4,33	0,065	0,74%	32,7%
139	3	Vanuatu	0,609	2	0,00	0,00	0,000	0,00%	16,0%
140	3	Zambia	0,584	1 173	50,75	19,48	0,074	1,66%	3,3%
141	3	Zimbabwe	0,571	1 321	114,94	31,99	0,457	2,42%	20,0%
142	4	Argentina	0,845	11 850	83,01	256,44	0,278	2,16%	69,1%
143	4	Austria	0,922	13 849	184,35	145,47	1,736	1,05%	63,9%
144	4	Belgium	0,931	17 394	314,73	241,28	1,762	1,39%	71,7%
145	4	Estonia	0,892	17 730	335,35	143,30	2,264	0,81%	54,3%
146	4	France	0,901	13 067	599,65	182,73	1,690	1,40%	72,9%
147	4	Germany	0,947	8 252	301,82	130,81	3,036	1,59%	65,4%
148	4	Iceland	0,949	6 433	589,48	10,78	0,291	0,17%	66,2%
149	4	Ireland	0,955	13 505	733,65	118,20	1,104	0,88%	72,0%
150	4	Israel	0,919	15 466	77,12	93,73	0,091	0,61%	67,2%
151	4	Italy	0,892	9 065	315,39	225,41	1,489	2,49%	70,5%
152	4	Latvia	0,866	14 420	277,08	239,80	3,696	1,66%	50,1%
153	4	Liechtenstein	0,919	15 414	588,24	175,16	0,000	1,14%	66,7%
154	4	Luxembourg	0,916	15 415	415,24	142,72	1,575	0,93%	61,2%
155	4	Malta	0,895	9 727	492,57	106,82	0,452	1,10%	88,1%
156	4	Netherlands	0,944	17 555	551,82	119,84	1,910	0,68%	66,0%
157	4	Norway	0,957	6 573	435,50	23,00	1,006	0,35%	71,4%
158	4	Portugal	0,864	12 220	359,48	185,12	1,229	1,51%	72,1%
159	4	Serbia	0,806	14 786	90,89	143,58	2,449	0,97%	36,6%
160	4	Seychelles	0,796	24 517	230,52	127,39	0,000	0,52%	79,1%
161	4	Slovenia	0,917	21 742	388,70	286,23	0,866	1,32%	50,2%
162	4	Spain	0,904	12 076	476,22	190,26	0,528	1,58%	71,6%
163	4	Sweden	0,945	12 483	251,11	150,18	0,187	1,20%	70,2%
164	4	Switzerland	0,955	13 884	516,62	133,56	1,193	0,96%	62,9%
165	4	United States of America	0,926	15 347	340,86	241,43	2,787	1,57%	59,6%
166	5	Bosnia and Herzegovina	0,78	8 772	97,04	405,21	4,903	4,62%	22,1%
167	5	Bulgaria	0,816	10 587	141,58	440,20	7,424	4,16%	20,6%
168	5	Croatia	0,851	16 728	498,87	297,09	8,501	1,78%	46,7%
169	5	Czechia	0,9	22 707	525,89	331,81	5,128	1,46%	57,5%
170	5	Georgia	0,812	23 083	438,19	333,91	9,322	1,45%	24,7%
171	5	Greece	0,888	10 124	313,29	194,07	5,525	1,92%	61,1%
172	5	Hungary	0,854	12 843	249,24	397,62	9,664	3,10%	58,9%
173	5	Lithuania	0,882	18 883	381,92	268,53	6,097	1,42%	57,7%
174	5	Montenegro	0,829	25 741	228,48	380,22	3,184	1,48%	37,5%
175	5	Poland	0,88	10 629	301,55	247,23	8,305	2,33%	48,4%
176	5	Russian Federation	0,824	7 072	128,16	206,47	4,967	2,92%	43,6%
177	5	Saint Lucia	0,759	7 163	56,40	159,98	6,508	2,23%	26,2%

178	5	Slovakia	0,86	15 007	463,80	297,38	9,321	1,98%	44,3%
179	5	Trinidad and Tobago	0,796	6 171	337,69	188,05	13,183	3,05%	46,9%