Supplementary Information for: Worldwide clustering and infection cycles as universal features of multiscale stochastic processes in the SARS-CoV-2 pandemic

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I. TABLES

Groups of countries and provinces as communities identified by the spectral analysis corresponding to three leading eigenvalues in the connected component of the correlation network for the threshold $\theta = 0.5$ for the first eight months (outbreak) and the last eight months (immunisation) networks; these networks are shown in Fig. 3 in the main text:

A. Outbreak phase Groups G1,G2,G3: clusters

Names of the countries and provinces in the group G1 belonging to four different clusters are shown in Table S1. Similarly, the group G2 consists of five clusters, listed in Table S2, and the five clusters belonging to the group G3 are shown in Table S3.

B. Immunisation phase Groups g1,g2,g3: clusters

The immunisation phase network shows a similar structure. However, the names of countries and provinces that group together differ almost entirely from those seen in the outbreak phase. The names corresponding to the identified clusters in the groups g1,g2, and g3 are listed in Tables S4, S5, and S4, respectively.

II. FIGURES

A. Networks at zero threshold and network's overlap at $\theta = 0.5$

We show the correlation networks at the zero thresholds, both for the outbreak and immunisation phase studied in this work, see Fig. S1. These networks contain all 255 nodes in the connected component and more links, specifically 15128 for the outbreak and 16850 for the immunisation network. They have a large density (ρ =0.467, and 0.52) and a high clustering coefficient ($< Cc >$=0.78, and 0.76) for the outbreak and immunisation period, respectively. Notably, the corresponding networks at zero thresholds already show a community structure with three communities, particularly prominent in the outbreak phase, which persists at the higher threshold values. Additionally, Fig. S2 illustrates the differences between the outbreak and immunisation network measured by the preserved links, as mentioned in the main text.

B. Time series cycles, Hurst exponents, and multifractality

Figure S3 complements the main text Fig. 7, showing that the infection cycles occur in both phases; moreover, they are more pronounced in the immunisation phase, even though the selected countries have a respectively high percentage of the vaccinated population. The fluctuations around these cycles, shown in Fig. S5, have certain multifractal properties, especially for small-scale fluctuations (for negative q values), and they are specific for each considered country.

Supplementary Table S1: *Outbreak phase*: Clusters of countries/regions belonging to the community $G1$.

G1c1	G1c2	g1c3	G1c4
Australia-Western-Australia	China-Hubei	Tajikistan	Australia-Capital-Territory
Canada-Nova-Scotia			Australia-Northern-Territory
China-Anhui; China-Beijing			Australia-Tasmania; Barbados; Brunei
China-Chongqing			Canada-Newfoundland-a.Labrador
China-Guangdong			Canada-Prince-Edward-Island
China-Heilongjiang			China-Fujian; China-Gansu; China-Guangxi; China-Hainan
China-Henan; China-Hunan			China-Hebei;China-Inner-Mongolia; China-Jilin
China-Jiangsu; China-Jiangxi			China-Liaoning; China-Ningxia; China-Shaanxi
China-Shandong			China-Shanxi; China-Sichuan; China-Tianjin; China-Yunnan
China-Shanghai			Denmark-Faroe-Islands; Denmark-Greenland; Fiji
China-Zhejiang			France-New-Caledonia; Grenada; Laos; Mauritius
New Zealand			Saint-Kitts-a.Nevis; Timor-Leste; UK-Anguilla
Niger; San-Marino; Tanzania			UK-Bermuda; UK-Cayman-Islands; UK-Falkland-Islands
UK-Channel-Island			UK-Isle-of-Man; UK-Montserrat

Supplementary Table S2: *Outbreak phase*: Clusters of countries/regions belonging to the community $G2$.

G2c1	G2c2	G2c3	G2c4	G2c5
Bangladesh	Brasil	Afghanistan; Algeria; Australia-N.South-Wales	Russia	Peru
Chile		Australia-Queensland; Australia-South-Australia	South-Africa	
Germany		Azerbaijan; Bahrain; Belarus; Belgium; Benin; Bolivia		
Italy		Cameroon; Canada-Ontario; Canada-Quebec		
Kazakhstan		Central-African-Republic; Chad; China-Macau		
Pakistan		Congo(Brazzaville); Congo(Kinshasa); Cote-d'Ivoire		
Saudi-Arabia		Djibouti; Dominican-Republic; Egypt; El-Salvador		
United-Kingdom		Eswatini; Finland; France-French-Guiana; Gabon; Gambia		
		Ghana; Guatemala; Haiti; Honduras; Kuwait; Kyrgyzstan		
		Liberia; Madagascar; Malawi; Malaysia; Mali; Mauritania		
		Nigeria; Oman; Panama; Papua-New-Guinea; Qatar		
		Rwanda; Senegal; Seychelles; Sierra-Leone; Singapore		
		Somalia; South-Sudan; Sri-Lanka; Sudan; Suriname		
		Sweden; Taiwan*; Thailand; United-Arab-Emirates		
		UK-Turks-a.Caicos-Islands;Uzbekistan; Yemen; Zambia		

Supplementary Table S3: *Outbreak phase*: Clusters of countries/regions belonging to the community $G3$.

G3c1	G3c2	G3c3	G3c4	G3c5
Albania; Andorra; Angola; Armenia	India	United States	Argentina	France
Australia-Victoria; Austria; Bahamas			Colombia	
Belize; Bhutan; Bosnia-a.Herzegovina			Czechia	
Botswana; Bulgaria;Burma; Cabo-Verde			Netherlands	
Canada-Alberta;Canada-British-Columbia			Poland	
Canada-Manitoba; Canada-Saskatchewan			Spain	
China-Hong-Kong; Costa-Rica;Croatia; Cuba;Cyprus				
Denmark; Dominica; Estonia; Ethiopia;				
France-French-Polynesia; France-Guadeloupe;				
France-Martinique;France-Reunion; France-St.Barthelemy				
France-St.Martin; Georgia; Greece; Guyana; Hungary				
Iceland; Indonesia; Iran; Iraq; Ireland; Israel				
Jamaica; Japan; Jordan; Kenya; Kosovo*				
Latvia; Lebanon; Lesotho; Libya; Liechtenstein				
Lithuania; Luxembourg; Malta; Moldova; Monaco				
Montenegro; Morocco; Mozambique				
Nepal; Netherlands-Aruba; Netherlands-Curacao				
Netherlands-St.Maarten; North-Macedonia				
Paraguay; Philippines; Saint-Lucia;				
Serbia; Slovakia;Slovenia; Switzerland; Syria				
Togo; Trinidad-a.Tobago; Tunisia; Ugand; Ukraine				
UK-Gibraltar; Uruguay; Vietnam; West-Bank-a.Gaza				

Supplementary Table S4: *Immunisation phase*: Clusters of countries/regions belonging to the community $g1$.

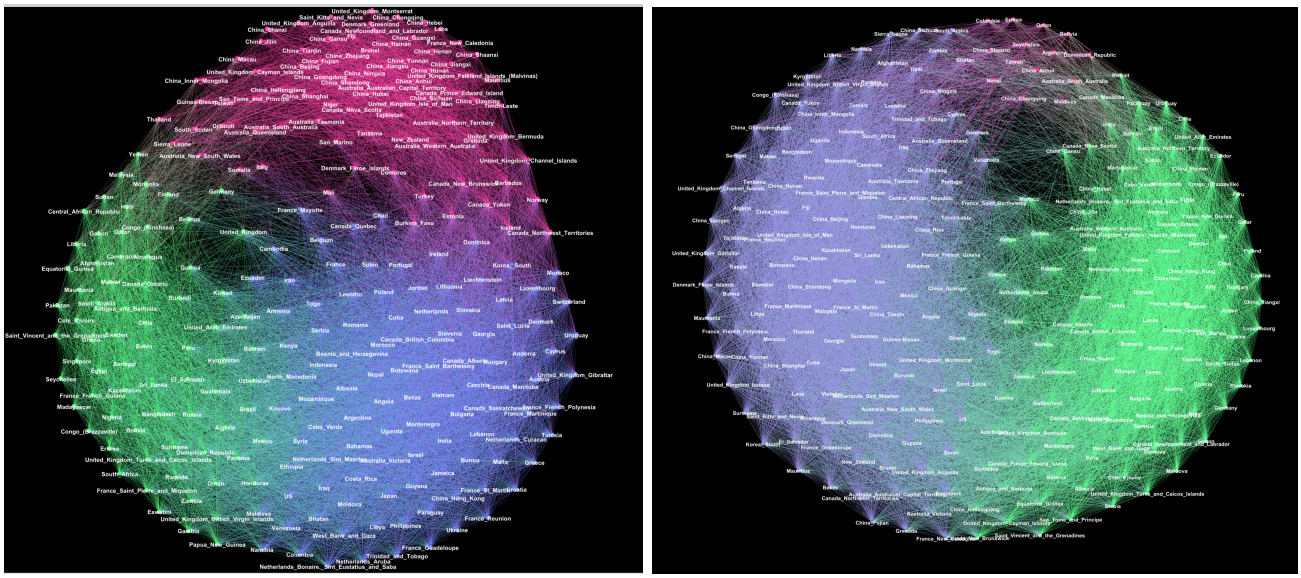
g1c1	g1c2	g1c3	g1c4
Afghanistan; Bahrain; Bhutan; Bolivia; Cabo-Verde;Cambodia	India	Brasil	Argentina
Canada-Manitoba; Canada-Nova-Scotia;Canada-Ontario; Canada-Yukon			Colombia
Chile; China-Anhui; China-Guangdong; China-Sichuan			South-Africa
Congo(Kinshasa); Dominican-Republic; Ecuador; Egypt; Eritrea;			
Haiti; Kuwait; Kyrgyzstan; Liberia; Madagascar; Maldives			
Namibia;Nepal; Oman; Panama; Paraguay; Saudi-Arabia;			
Seychelles; Sierra-Leone; Taiwan*; Trinidad-a.Tobago;			
Tunisia; United-Arab-Emirates; Uruguay; Zambia			

Supplementary Table S5: *Immunisation phase*: Clusters of countries/regions belonging to the community $g2$.

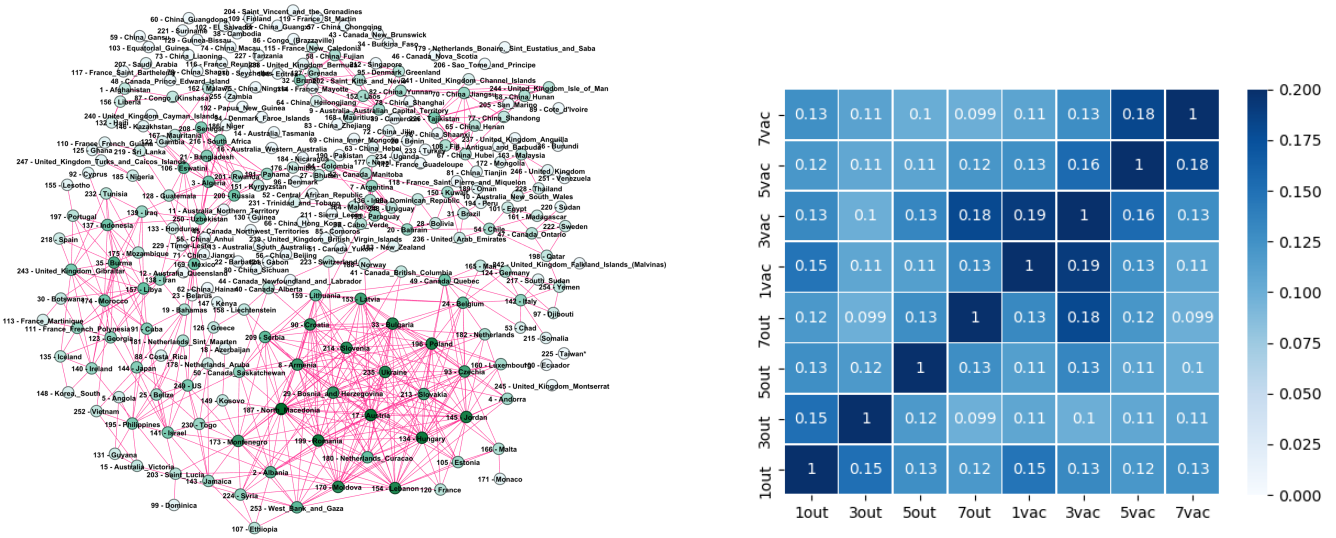
g2c1	g2c2	g2c3	g2c4	g2c5
Albania; Andorra; Armenia;Australia-Northern-Territory	France	Czechia	Turkey	Germany
Austria; Belarus; Belgium; Bosnia-a.Herzegovina		Hungary		Italy
Bulgaria; Burkina-Faso; Cameroon; Canada-Alberta		Jordan		Poland
Canada-British-Columbia; Canada-Newfoundland-a.Labrado		Netherlands		
Canada-Quebec; Canada-Saskatchewan		Peru		
Chad; China-Hong-Kong; China-Jiangxi; Comoros		Serbia		
Cote-d'Ivoire; Croatia; Djibouti; Estonia; Ethiopia		Sweden		
France-Mayotte; Gabon; Jamaica;Latvia; Lithuania		Ukraine		
Luxembourg; Mali; Malta; Moldova; Monaco				
Montenegro; Netherlands-Curacao;North-Macedonia				
Norway; Pakistan; Qatar; Romania				
San-Marino; Sao-Tome-a.Principe;Slovakia; Slovenia;				
Somalia;South-Sudan; Sudan; Switzerland				
Syria; UK-Falkland-Islands(Malvinas)				
UK-Turks-a.Caicos-Islands; West-Bank-a.Gaza; Yemen				

Supplementary Table S6: *Immunisation phase*: Clusters of countries/regions belonging to the community $g3$.

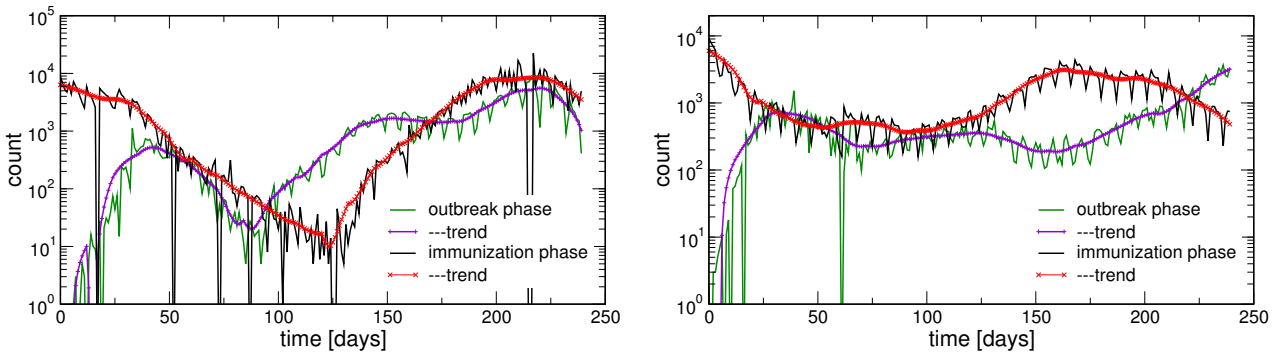
g3c1	g3c2	g3c3	g3c4	g3c5
Algeria; Angola; Australia–Capital-Territory	United-States	Iran	Bangladesh	Spain
Australia-New-South-Wales;Australia-Queensland		United-Kingdom	Japan	
Australia-Tasmania; Australia-Victoria			Malaysia	
Azerbaijan; Bahamas; Belize; Benin			Mexico	
Botswana; Brunei; Burma;Burundi			Philippines	
Canada-Northwest-Territories			Russia	
China-Fujian; China-Henan; China-Hubei			Thailand	
China-Hunan; China-Jiangsu; China-Shandong			Vientnam	
China-Shanghai; China-Tianjin; China-Yunnan				
Costa-Rica; Cuba; Cyprus				
Denmark-Faroe-Islands; Denmark-Greenland				
Dominica; Eswatini; Fiji				
France-French-Guiana; France-French-Polynesia				
France-Guadeloupe; France-Martinique				
France-New-Caledonia; France-Reunion				
Gambia; Georgia; Grenada; Guatemala				
Guinea-Bissau; Guyana; Honduras; Iceland				
Iraq; Ireland; Israel; Kazakhstan				
Korea-South; Laos; Lesotho; Libya				
Mauritania; Mauritius; Mongolia; Morocco				
Netherlands-Aruba; Netherlands-St.Maarten				
New-Zealand; Nicaragua; Portugal				
Sain-Kitts-a.Nevis; Saint-Lucia; Singapore				
Sri-Lanka; Suriname; Tajikistan; Timor-Leste				
UK-Anguilla; UK-Cayman-Islands;UK-Gibraltar				
UK-Isle-of-Man;Uzbekistan				



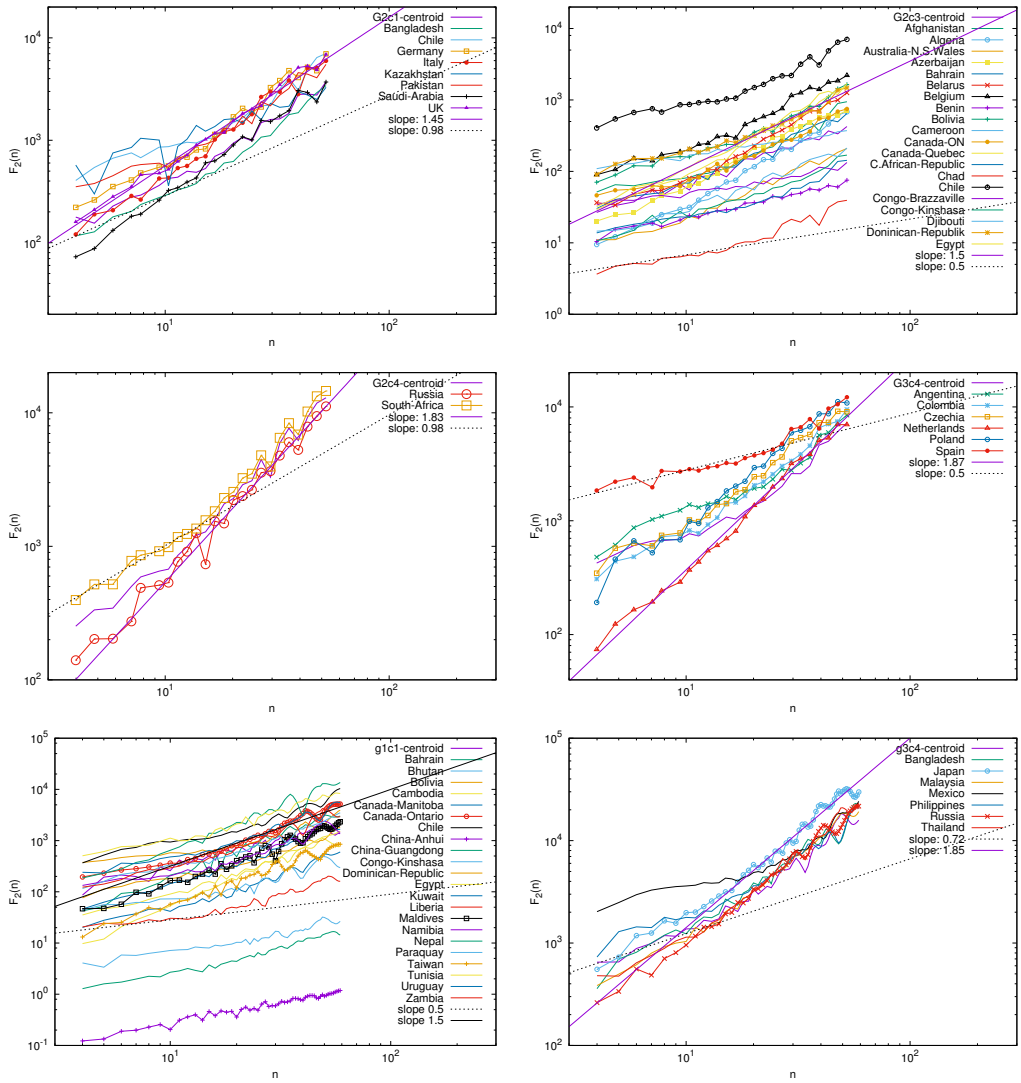
Supplementary Figure S1: The networks containing all positive correlations (threshold $\theta = 0$) for the outbreak (left) and immunisation phase (right); communities are indicated by a different colour.



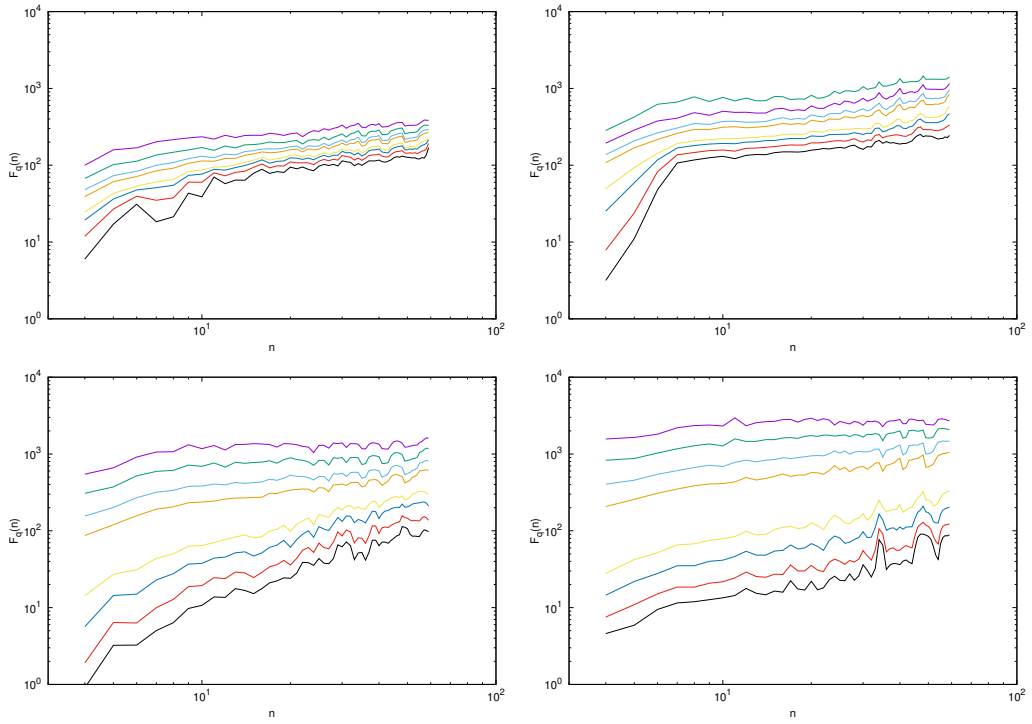
Supplementary Figure S2: Left: The edges appearing in both the outbreak and immunisation periods networks with the threshold $\theta = 0.5$, depicted in Fig. 3 in the main text. Right: The overlap level measured by the Jaccard index between networks mapping the successive two-months periods during the outbreak and immunisation phase.



Supplementary Figure S3: Comparisons of the outbreak and immunisation phases. Cyclic trends in the incidence rates data for two countries with a significant immunisation coverage (Israel, left, and Portugal, right).



Supplementary Figure S4: Fluctuation function $F_2(n)$ vs n for several identified clusters G2c1, G2c3 (part), G2c4, and G3c4 clusters in the outbreak phase, and g1c1 (part) and g3c4 clusters in the immunisation phase, mentioned in the main text.



Supplementary Figure S5: Fluctuations around the cyclic trend differ in the outbreak and immunisation phase. Two examples of the multifractal function $F_q(n)$ vs interval length n for the time series data in the outbreak phase (left) and vaccination (right): top panels are for Portugal, bottom panels for Israel time-series data. In each panel, top to bottom lines are for q =4,2,1 0.5, -0.5,-1,-2, -4, respectively.