Overlapping Time Scales Obscure Early Warning Signals of the 2nd COVID-19 Wave

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Background

Early warning signals for COVID-19:

- $-R_t = 1$ constitutes a (dynamic) transcritical bifurcation.
- This motivates early warning signals based on critical slowing down [1].
- Do early warning indicators rise prior to the 2^{nd} COVID-19 wave?

We investigated this by analyzing 27 European countries and via simulations [2].

Empirical Analysis

Simulation Study



We used a simple stochastic SEIR model calibrated to COVID-19 to explain our empirical findings.

Illustration

We vary $R_t = \frac{\beta(t)}{\gamma}$ as illustrated in Figure 3, which shows that indicators tend to *decrease* rather than *increase* due to the persistent transient from the first wave.

We estimated R_t to (a) select an appropriate time period between the first and second wave, (b) detrended the reported cases, and (c) estimated early warning indicators using backwards rolling windows, as Figure 1 illustrates on a simulated example.





Figure 3: Early warning indicators increase prior to a second outbreak in case the epidemic can settle down (a) but decrease in case it cannot settle down (b).

Simulation Results

We varied the time for which $R_t = 0.50$ and the time until $R_t = 1$. As these times



Figure 1: Illustrates our methodology and shows four example countries.

Empirical Results

Figure 2 shows that indicators tended to *decrease* rather than *increase*.

Kendall's τ for early warning indicators across countries



decrease, so do the area under the curve and the true positive rate, mirroring our empirical findings; widely used testing methodology is poorly calibrated at $\alpha = 0.05$.



Figure 2: Summary of results across countries and indicators for $\delta_1 = 4$ and $\delta_2 = 25$. Red points indicate countries for which Kendall's τ was either significantly smaller or larger than expected under a stationary time-series at $\alpha = 0.05$.

Figure 4: Area under the curve (a) and true positive rate (b) for ten early warning indicators.

Conclusion

- Early warning indicators did not reliably rise prior to the 2^{nd} COVID-19 wave.
- Indicators tended to decrease due to a persistent transient from the first wave.
- Time scale separation is important in applications of critical slowing down.

References

- 1. O'Regan, S. M. & Drake, J. M. Theory of early warning signals of disease emergence and leading indicators of elimination. *Theoretical Ecology* **6**, 333–357 (2013).
- 2. Dablander, F., Heesterbeek, H., Borsboom, D. & Drake, J. M. Overlapping Time Scales Obscure Early Warning Signals of the Second COVID-19 Wave. *MedRxiv.* doi:10.1101/2021.07. 27.21261226 (2021).