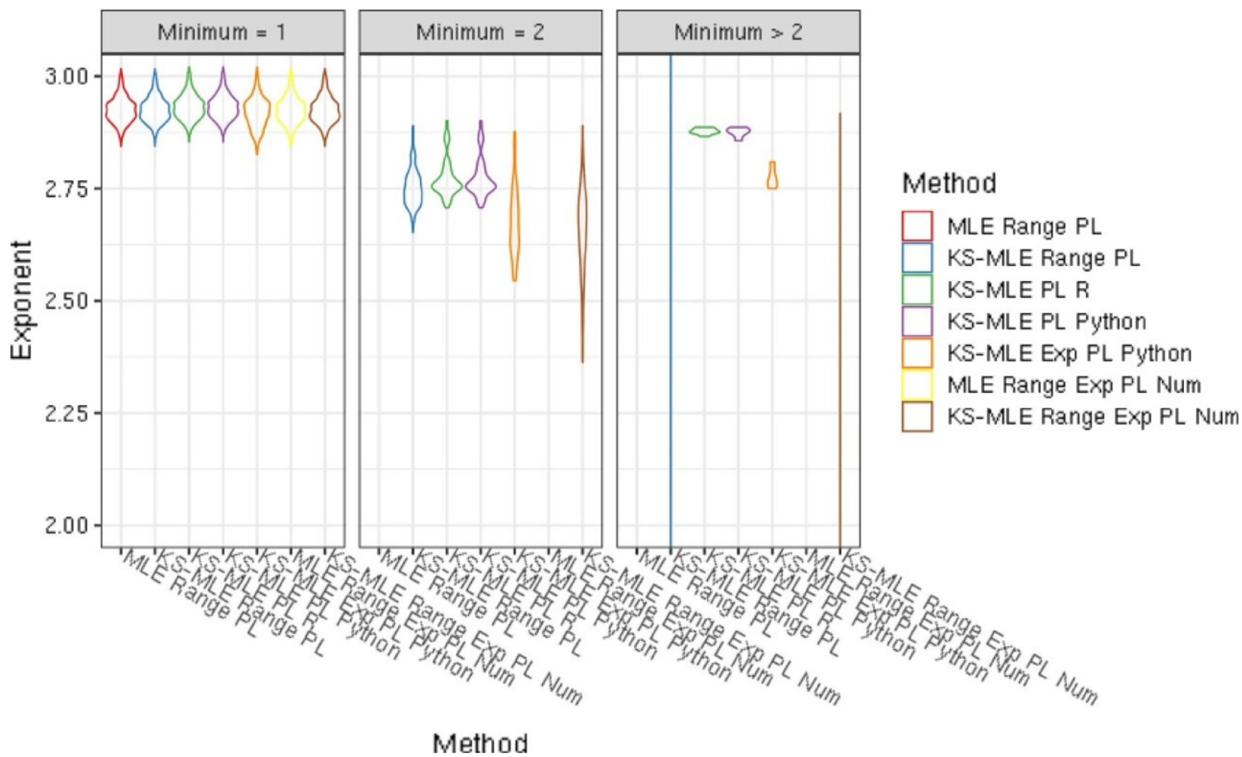
Coalescence-fragmentation cycles based on human conflict

March 21 2024, by Rachel Berkowitz



Distribution of power-law exponents for various fitting methods. Power-laws are fitted to a coalescence and fragmentation process simulated with size-biased kernels as in (2, 3), $M = 10^4$, $F = 0.3$, and 20,000 samples. We write MLE and KS-MLE as in the main text, "PL" for power law, "Range" for finite range, "Exp" for an exponential cut-off, "R" for the poweRlaw package, "Python" for the powerlaw package, and "Num" for the numerical maximum likelihood estimation in the bbmle package. The theoretical value is 2.5, which all methods deviated from with varying amounts of bias. Credit: *The European Physical Journal B* (2024). DOI: 10.1140/epjb/s10051-024-00654-y

In 1960, Lewis Fry Richardson famously observed that the severity of a wartime event is described by a simple power law distribution that scales according to the size of the conflict. Statisticians have since proposed various modifications, but they continue to agree that the casualty count in a violent conflict tends to scale with the size of the insurgent group that caused the conflict.

In a study published in *The European Physical Journal B*, Brennen Fagan, of the University of York, UK, and his colleagues analyze models of how complex systems coalesce and fragment based on these warfare dynamics. Their work evaluates the robustness of these models and elucidates the relationship between microscopic dynamics and observed phenomena.

In finite populations, groups coalesce, and they fragment. These processes tend to balance one another, resulting in groups whose size distribution is described by a power law. Fagan surmised that these observed distributions result from the same basic self-organization that shapes human conflicts.

Complex systems also feature finer-scale changes in group distributions: gelation, where most of the population is absorbed into a single large group, and shattering, where large groups break into individuals. Moreover, models suggest an emergent phenomenon: stochastic cycles of gelling and shattering.

Fagan and his colleagues performed simulations to examine how standard models of coalescence and fragmentation vary with different underlying or additional rules common to applications. They found that the basic power law distribution persisted when individuals moved to and from randomly chosen groups and with partial rather than total shattering. But for broader distributions of fragment sizes, the gel-shatter cyclicity no longer occurred.

The results should be applicable to a wide variety of systems, ranging from the physical interactions between asteroids and dust to probabilistic, economic, biological, and social structures—such as the insurgent warfare that inspired the analysis.

The research is published in *The European Physical Journal B*.

More information: Brennen T. Fagan et al, Robustness of steady state and stochastic cyclicity in generalized coalescence-fragmentation models, *The European Physical Journal B* (2024). DOI: 10.1140/epjb/s10051-024-00654-y

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