Infinite variance of U.S. COVID-19 cases and deaths, and Taylor's law of heavy-tailed data

Joel E. Cohen, The Rockefeller University and Columbia University, New York

2022-07-28, 8:45am U.S. Eastern time

Abdus Salam International Centre for Theoretical Physics

Workshop on Quantitative Human Ecology (smr 3728) (25-29 July 2022)

Over the last century, ecologists, statisticians, physicists, financial quants, and others discovered, in many sets of samples of nonnegative quantities, such as population sizes or stock prices, that the sample variance approximates a power of the sample mean. This power-law relationship of variance to mean is known as a power variance function in statistics, as Taylor's law in ecology, and as fluctuation scaling in physics and financial mathematics. This survey talk will emphasize ideas, motivations, recent theoretical results, applications, and practical implications rather than proofs. Many models of Taylor's law assume the probability distribution underlying each sample has finite mean and variance. Recently, colleagues and I generalized Taylor's law to samples from probability distributions with infinite mean or infinite variance. For such heavy-tailed distributions, we extended Taylor's law to higher moments than the mean and variance and to measures of upside and downside portfolio risk. U.S. COVID-19 cases and deaths illustrate Taylor's law with finite means and infinite variances. This finding has practical implications. Collaborators in this work are Mark Brown, Richard A. Davis, Victor de la Peña, Gennady Samorodnitsky, Chuan-Fa Tang, and Sheung Chi Phillip Yam.

References

Brown, Mark, Cohen, Joel E. and de la Peña, Victor 2017 Taylor's law, via ratios, for some distributions with infinite mean. Journal of Applied Probability 54(3):1-13 doi:10.1017/jpr.2017.25

Brown, Mark, Cohen, Joel E., Tang, Chuan-Fa, and Yam, Sheung Chi Phillip 2021 Taylor's law of fluctuation scaling for semivariances and higher moments of heavy-tailed data. Proceedings of the National Academy of Sciences U.S.A. 118(46):e2108031118 https://doi.org/10.1073/pnas.2108031118

Cohen, Joel E., Davis, Richard A., and Samorodnitsky, Gennady 2020 Heavy-tailed distributions, correlations, kurtosis, and Taylor's law of fluctuation scaling. Proceedings of the Royal Society A 476:20200610. https://doi.org/10.1098/rspa.2020.0610

Cohen, Joel E., Davis, Richard A., and Samorodnitsky, Gennady 2022 COVID-19 cases and deaths in the United States follow Taylor's law for heavy-tailed distributions with infinite variance. *Proceedings of the National Academy of Sciences* under review

Eisler, Zoltán, Bartos, Imre and Kertesz, János 2008 Fluctuation scaling in complex systems: Taylor's law and beyond. Advances in Physics 57(1):89-142. DOI: 10.1080/00018730801893043 arXiv:0708.2053v2 [physics.soc-ph]

Taylor, R. A. J. 2019 Taylor's Power Law: Order and Pattern in Nature. Elsevier Academic Press, Cambridge, MA.