Novel Statistical Physics Approaches to Understanding Economic Fluctuations

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I. INTRODUCTION

Recent analysis of truly huge quantities of empirical data suggests that classic economic theories not only fail for a few outliers, but that there occur similar outliers of every possible size. Specifically, if one analyzes only a small data set (say 10^4 data points), then outliers appear to occur as "rare events." However, when we analyze orders of magnitude more data (10^8 data points), we find orders of magnitude more outliers—so ignoring them is not a responsible option, and studying their properties becomes a realistic goal. We find that the statistical properties of these "outliers" are identical to the statistical properties of everyday fluctuations. For example, a histogram giving the number of fluctuations of a given magnitude x for fluctuations ranging in magnitude from everyday fluctuations to extremely rare fluctuations that occur with a probability of only 10^{-8} is a straight line in a double-log plot, so one can quantify the probability of an event of any given size.

II. TWO UNIFYING PRINCIPLES

Two unifying principles that underlie much of the finance analysis we will present are scale invariance and universality.[1] Scale invariance is a property not about algebraic equations but rather about functional equations, which have as their solutions not numbers but rather functional formbs power laws, e.g., the solution of trhe functional equation $f(\lambda x) = \lambda^p f(x)$ is $f(x) = x^p$. The key idea of universality is that the identical set of "scaling laws" hold across diverse markets, and over diverse time periods, e.g., the inverse cubic law for price changes seems to hold for a huge range of indices.

We demonstrate the principles of scaling and universality by describing very recent work.[2–4] Financial market fluctuations are characterized by many abrupt switchings on very short time scales from increasing "microtrends" to decreasing "microtrends"—and vice versa. We ask whether these ubiquitous switching processes have quantifiable features analogous to those present in phase transitions, and find striking scale-free behavior of the time intervals between transactions both before and after the switching occurs. We interpret our findings as being consistent with timedependent collective behavior of financial market participants.

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III. THE FRAGILITY OF INTERDEPENDENCY: INTERDEPENDENT NETWORKS & SWITCHING PHENOMENA IN ECONOMIC SYSTEMS

Recent disasters ranging from financial "shocks" to large-scale power and terrorists attacks dramatically exemplify the fact that the most dangerous vulnerability is hiding in the many interdependencies among different networks. We quantify failures in interconnected networks, and demonstrate the need to consider mutually dependent network properties in designing resilient systems. Specifically, we have uncovered new laws governing the nature of switching phenomena in coupled networks, and found that phenomena that are continuous "second order" phase transitions in isolated networks become discontinuous abrupt "first order" transitions in interdependent networks.[2,5] For example, we find that the same laws governing the formation and bursting of the largest financial bubbles also goven the tiniest finance bubbles, over a factor of 1,000,000,000 in time scale.[3,4]

IV. PREDICTING THE FUTURE

Finally, we demonstrate that by analyzing changes in Google query volumes for search terms related to finance, we find patterns that may be early warning signs of stock market moves.[6] We conclude by discussing the network basis for understanding sudden death in the elderly, and the possibility that financial "flash crashes" are not unlike the catastrophic first-order failure incidents occurring in interdependent networks.[7]

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