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The pre-history of econophysics and the history of economics: Boltzmann versus the marginalists

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HIGHLIGHTS

- A comparative intellectual history of econophysics and economic science is provided to demonstrate why and how econophysics is distinct from economics.
- The history and role of the ergodicity hypothesis of Ludwig Boltzmann is considered.
- The use of phenomenological methods in econophysics is detailed.
- The role of ergodicity in empirical estimates of models in economics is identified.

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ABSTRACT

This paper contrasts developments in the pre-history of econophysics with the history of economics. The influence of classical physics on contributions of 19th century marginalists is identified and connections to the subsequent development of neoclassical economics discussed. The pre-history of econophysics is traced to a seminal contribution in the history of statistical mechanics: the classical ergodicity hypothesis introduced by L. Boltzmann. The subsequent role of the ergodicity hypothesis in empirical testing of the deterministic theories of neoclassical economics is identified. The stochastic models used in modern economics are compared with the more stochastically complex models of statistical mechanics used in econophysics. The influence of phenomenology in econophysics is identified and discussed.

> "Rational mechanics gives us a first approximation to theory of the equilibrium and of the movements of bodies. In the same way the theories of Jevons, Walras, Marshall, Fisher, and others present us with a first approximation to the theory of economic phenomena."
>
> Vilfredo Pareto [1]

1. Introduction

At least since Mirowski [2], it has been widely recognized that important theoretical elements of neoclassical economics were adapted from mathematical concepts developed in 19th century classical physics. Much effort by historians of economic

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thought and others has been dedicated to exploring the validity and implications of "Mirowski's thesis" [3–7], especially the connection between the deterministic 'rational mechanics' approach of classical physics and the subsequent development of neoclassical economic theory [8–10]. This well traveled literature connecting classical physics with neoclassical economics is seemingly incongruent with emergence of the distinct subject of econophysics during the last decade of the twentieth century. Appearing primarily in physics journals, econophysics is now a "recognized field" [11] within physics that involves the application of empirical and theoretical methods from statistical mechanics to the analysis of economic phenomena, e.g., [12–18]. This paper uses comparative intellectual history to illustrate how econophysics differs from mainstream economics.

Contributions to econophysics range from empirical studies on scaling and power law distribution properties of financial data to theoretical studies of multi-agent order flow models, e.g., [19,20]. The common theme is application of methods from statistical mechanics to economic phenomena. Significantly, there are contributions by economists stretching back to the work of Pareto on the scaling law for wealth that overlap with this theme. There are also some contributions in economics journals that do not differ substantively from contributions to econophysics appearing in physics journals. Is it possible that 'econophysics' differs from 'economics' not on specific content or methodology but, rather, on the discipline of the scholarly journals publishing the research? Contrasting the history of economics with the pre-history of econophysics, this paper demonstrates how and why econophysics is methodologically and philosophically distinct from mainstream economics. The introduction into economics by Francis Ysidro Edgeworth (1845–1926) and other marginalists of mathematical methods adapted from classical physics is connected to the contemporaneous introduction of ergodicity to statistical mechanics by Ludwig Boltzmann (1844–1906). Tracing the subsequent historical evolution of stochastic concepts in economics reveals a specific form of the ergodicity hypothesis being adopted in econometric modeling while statistical mechanics was in the process of developing a richer variety of stochastic models that are now being phenomenologically employed in econophysics.

As Mirowski [21–24] is at pains to emphasize, physics has evolved considerably from the deterministic classical approach which inspired neoclassical economics. In discussing historical developments in physics, Mirowski, Sornette [17] and others often jump from the determinism of rational mechanics to the stochastic behavior of Ising models and quantum mechanics to recent developments in chaos theory, overlooking the relevance of initial steps toward stochastic modeling of physical phenomena by Ludwig Boltzmann, James Maxwell (1831–1879) and Josiah Willard Gibbs (1839–1903).[2] Introduction of the 'ergodicity hypothesis' by Boltzmann around the time that *Mathematical Psychics* by Edgeworth appeared in 1881 provides an important connection between the history of economics and the pre-history of econophysics. The subsequent emergence and development of stochastic concepts in econometrics adopted a form of ergodicity to empirically test the deterministic models of neoclassical economic theory. In this process, ergodicity permitted statistical techniques designed for repeatable experiments of the natural sciences to be extended to the non-experimental data of economic phenomena.

Early contributors to the econometrics project featured training in physics or mathematical statistics, subjects where ergodic concepts are employed. Consequently, stochastic generalization of the deterministic and static equilibrium models of neoclassical economic theory adopted 'time reversible' ergodic probability models, such as the likelihood functions associated with (possibly transformed) stationary Gaussian error distributions. By this time, stochastic representations in statistical mechanics had evolved considerably from the early ergodic models of Boltzmann to include Ising models of interacting elements and quantum mechanics. The stochastic models of statistical mechanics now available to econophysics include a wide variety of non-linear, irreversible and chaotic stochastic models aimed at capturing key empirical characteristics of different physical and economic phenomena. In addition to scaling and power laws, these models include truncated Levy processes as well as the fractals and chaos theory popularized by Mandlebrot. Application of these models often employ phenomenological methods that vary substantively from the methods associated with the stochastic representations of modern economic theory that are based on constrained optimization solutions for consumers, producers and investors derived from axiomatic choice theory.

Comparing the history of economics with the pre-history of econophysics reveals substantive differences in methodology that restrict straightforward adoption in mainstream economics of models used econophysics. As Roehner [11] observes: "From a methodological perspective, the strong emphasis econophysics has put on the search for regularities is probably one of its most important innovations. In contrast, for most economists a quantitative regularity is considered of no interest unless it can be interpreted in terms of agents' motivation and behavior and has a clearly defined theoretical status". The process of adapting stochastic models from statistical mechanics to econophysics involves letting the data determine the appropriate stochastic model, e.g., cross correlation analysis, before proceeding to theoretical explanation, if any. In contrast, in mainstream economics stochastic representation of economic phenomena involves initial development of a theoretical model based on axiomatic propositions about rational economic behavior, before proceeding to determine the statistical 'fit' of the data to the theoretical model.

Schinckus [27] explores the positivist philosophical foundation of econophysics identifying the fundamental role of empirical observation: "The empiricist dimension is …the first positivist feature of econophysics". For McCauley [28] and others, this concern with empiricism involves the use of phenomenological methods to identify macro-level statistical regularities that are characterized by scaling and power laws, such as those identified by Mandelbrot [29] and Mandelbrot

[2] Cercignani [25] discusses the connection between Boltzmann and the energetists of that time. Volovich [26] details the differences between classical and quantum mechanics.