

Towards Realistic and Explainable Market Simulations: Factorizing Financial Power Law Using Optimal Transport

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Abstract : This study aims to analyze the mechanism underlying the power law of stock returns through artificial market simulations. Although traditional financial theory postulates a Gaussian distribution for stock price fluctuations, empirical evidence indicates that the tail distribution of these fluctuations follows a power law. Research motivated by this gap has proposed various hypotheses regarding the components that generate power laws in financial price fluctuations. One hypothesis attributes the power law to investor behavior, whereas the other points to the demand distribution of institutional investors. However, existing research has not simultaneously modeled these components to study their individual contributions to the power law and their interactions. The complexity of real financial markets complicates the isolation of the contribution of a single component using existing data. To determine the extent to which each component contributes to the formation of this stylized fact and the effect when multiple components are present simultaneously, this study utilizes artificial markets and optimal transport (OT) to conduct controlled experiments. Artificial markets have been used for both financial counterfactual analysis and synthetic data generation, facing trade-off between explainability and realism. The proposed pipeline of hypotheses evaluation cycles of agent models based on quantitative evaluation using OT tackles this trade-off by examining the impact of each component in the agent model on the realism of the simulation, providing insights into why the simulations are able to reproduce real-world phenomena. The experiments revealed that the informational effect of prices plays a dominant role in generating realistic power law distributions, and a synergistic effect exists among multiple components.

Keywords : power law, artificial market, multi-agent simulation, optimal transport, financial synthetic data

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