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A Simple Econophysics Model of the Stock Market as a Nonequilibrium Open System

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Motivation

- “Importing” methods of mathematical modeling from physics and applying them to various proplems in economics.
- Common probability models often fail to explain some features of financial time series
- Given a particular time series, it is complicated to reconstruct the corresponding dynamical system
- Following the principles of physico-mathematical modelling implies constructing the model “ab inito”

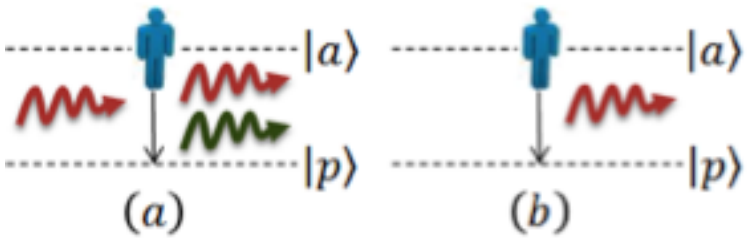
Model Assumptions

1. Stock market is a macroscopic system.
   - Stock market is a dynamical system that consists of numerous market agents ($N >> 1$).
   - Modeling of such systems does not require detailed analysis of interactions between the agents on the micro-level.
   - For macroscopic dynamic variables we have chosen aggregated flows of **ask** and **bid** price changes and dynamical difference of market agents in specific states.
2. Stock market is a point autonomous dynamical system.

$$\dot{\mathbf{X}} = \mathbf{F}(\mathbf{X}, \beta)$$

Model Assumptions

3. Every market agent can be either in active $|\alpha\rangle$-state or passive $|p\rangle$-state.
   - market agent in $|\alpha\rangle$-state has maximum amount of valuable information I_α and has minimum information I_p otherwise.
   - Agent in $|\alpha\rangle$-state can generate an “ask-quantum” to other agents.
   - Agent in $|p\rangle$-state can ignore it or generate “bid-quantum” in response.



Model Assumptions

4. Stock market is a nonequilibrium open system.
   - Information flow from external sources "pump up" the stock market

     $$N_\alpha >> N_p,$$

     where N_α is number of "active agents" and N_p is number of "passive agents".
   - With acceptable accuracy, the distribution of number of agents by their states can be represented as follows

     $$N_\alpha = N_p \exp\left(-(I_\alpha - I_p)/\Theta\right)$$

     where Θ is average intensity of stochastic interactions between market agents

Dynamic Variables

- Variation of ask price relative to equilibrium value

$$x_1(t) \equiv X_{ask}(t) - X_{ask}^{eq}$$

- Variation of bid price relative to equilibrium value

$$x_2(t) \equiv X_{bid}(t) - X_{bid}^{eq}$$

- instantaneous difference between numbers of agents in $|\alpha>$-state and $|p>$-state

$$x_3(t) \equiv N_\alpha - N_p$$

- Dynamical system (Lorenz–Haken equation)

$$\begin{cases} \dot{x_1} = -\alpha x_1 + \beta x_2 \\ \dot{x_2} = -\gamma x_2 + c x_1 x_3 \\ \dot{x_3} = (I_0 - x_3) + k x_1 x_2. \end{cases}$$

Conclusions

This model **can** explain:

- Unrealizability of equilibrium state of the market
- Deterministic chaos in the market

This model **cannot** explain:

- Heavy-tailed distribution of financial time series
- Pink Noise occuring in financial time series

Results & Futher Research

- This model was presented during **2nd International Conference on: Applied Physics, System Science and Computers** (Dubrovnik, Croatia).
- Switch from “pure” differencial equations to stochastic differencial equations
- Add elements of Game Theory to improve market agents’ behaviour.

Thank you for your attention!

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