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Research paper

Herding, minority game, market clearing and efficient markets in a simple spin model framework

Ladislav Kristoufek[a,b,*], Miloslav Vosvrda[a,b]

[a] Institute of Information Theory and Automation, Czech Academy of Sciences, Pod Vodarenskou Vezi 4, Prague 182 08, Czech Republic
[b] Institute of Economic Studies, Faculty of Social Sciences, Charles University in Prague, Opletalova 26, Prague 110 00, Czech Republic

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ABSTRACT

We present a novel approach towards the financial Ising model. Most studies utilize the model to find settings which generate returns closely mimicking the financial stylized facts such as fat tails, volatility clustering and persistence, and others. We tackle the model utility from the other side and look for the combination of parameters which yields return dynamics of the efficient market in the view of the efficient market hypothesis. Working with the Ising model, we are able to present nicely interpretable results as the model is based on only two parameters. Apart from showing the results of our simulation study, we offer a new interpretation of the Ising model parameters via inverse temperature and entropy. We show that in fact market frictions (to a certain level) and herding behavior of the market participants do not go against market efficiency but what is more, they are needed for the markets to be efficient.

1. Introduction

Agent-based models (ABM) have attracted much attention in economics and finance in recent years [1–3] as they describe the reality better than simplified models of traditional economics and finance. The crucial innovation lies in assuming a boundedly rational economic agent [4,5] instead of a perfectly rational representative agent with homogeneous expectations [6,7]. In these models, agents make decisions without utility maximization but usually using simple heuristics. The resulting systems are usually driven endogenously, i.e. without exogenous shocks forcing the dynamics.

In finance, the founding contributions were laid by Brock and Hommes models [8,9] characteristic by strategy-switching agents and possible bifurcation dynamics. Essential contributions to the topic are the early papers of Lux and Marchesi [10] and Kaizoji [11] who introduce a possibility of generating the returns-like series from simple models based on interactions between multiple agents. They both serve as a starting point to an important branch of the ABMs which is based on a parallel between ferromagnetism and market dynamics, i.e. the Ising model adjusted for financial markets. In the models, economic agents participating in the market are spins of a magnet. In the same way as the spins, the agents are influenced by (make their decisions based on) their neighbors, or agents with similar beliefs, but also by the overall market sentiment and activity. The novel model of Bornholdt [12] combining the standard Ising model from physics with an additional term reminiscent of the minority game, i.e. the tendency of agents to lean away from the majority opinion when the majority prevails too much, has been shown to successfully mimic the basic financial stylized facts such as no serial correlation of re-

* Corresponding author.
E-mail addresses: kristouf@utia.cas.cz, ladislav.kristoufek@fsv.cuni.cz (L. Kristoufek), vosvrda@utia.cas.cz (M. Vosvrda).

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turns, persistence and clustering of volatility, and non-Gaussian distribution of returns. Kaizoji et al. [13] expand the model of Bornholdt [12] by four additional parameters to allow for simulations of the traded volume through the balance between supply and demand. Implications for bull and bear markets together with bubbles occurrence is discussed there as well.

These founding papers have led to various adjusted and generalized models trying mainly to fit the market data or mimic the stylized facts. Sornette and Zhou [14] build a model with external news and expectations of the agents, who are able to adjust their expectations through learning. Their model is able to generate fat-tailed returns with exponentially decaying serial correlation structure, aggregate normality, volatility power-law decaying serial correlation and clustering as well as specific multi-fractal properties. Compared to the basic model of Bornholdt [12] with two parameters, the model of Sornette and Zhou [14] uses seven. Zhou and Sornette [15] present further results of the same model with a more direct connection to behavioral finance as the agents are allowed to be not fully rational. Yang et al. [16] utilize a similar model and try to explain the dynamics of the KOSPI stock market. They show that one of the parameters is directly proportional to the tail index of the distributions with power-law tails. However, it is not clear whether this holds for reasonable values of other parameters as well.

Queiros et al. [17] present a model combining the ideas of Lux and Marchesi [10], Bornholdt [12] and Sornette and Zhou [14], explicitly including a term depending on magnetization. Even though the model is able to produce most of the stylized facts, it is not able to replicate the important features of volatility – clustering and power-law autocorrelation decay. Sieczka and Hołyst [18] expand the model of Kaizoji et al. [13] by allowing the agents to take three instead of standard two positions – in addition to “buy” and “sell”, there is also a possibility to stay inactive. The model is able to reproduce many stylized facts but the ones connected to volatility. Denys et al. [19] further enhance the model of Sieczka and Hołyst [18] by having opinions in their willingness to buy or sell which are only then translated into actual buying or selling actions. This opinion dynamics enters the neighbor interactions part of the model. Even thought the main motivation of the paper is to correct the Sieczka and Hołyst [18] study, this enhanced model still does not mimic the power-law decay in the volatility autocorrelation function. The idea of opinion forming in the financial Ising models is further developed in Krause and Bornholdt [20] where the volatility clustering is obtained.

Krawiecki [21] enriches the Ising-type models with a random organic network structure. Through three uniformly distributed random variables and three parameters, the model replicates the basic stylized facts even for volatility. Krause and Bornholdt [22] move towards a macroscopic model using the original microscopic model of Bornholdt [12] and Takaishi [23] generalizes the whole framework for multiple assets showing that cross-correlated assets can be generated. However, other stylized facts are not covered in detail.

For a detailed treatment and history of the Ising-type models in financial economics together with other agent-based models, we suggest the current treatment of the topic by Sornette [24].

There are at least three interesting outcomes that can be inferred from the review above. First, the results and ability of models to recover the financial stylized facts are often very sensitive to the parameters choice. Only a narrow range of parametric values yields reasonable results and the models usually break down in a sense that they converge to a very stable magnetization and thus price which results in zero returns. Second, majority of papers dealing with the financial Ising-type models focus primarily on retrieving the stylized facts of returns and volatility (and sometimes traded volume) and touch the interpretation of parametric values only on surface. And third, vast majority of the reviewed models are not able to outperform the original Bornholdt [12] model in the sense of the stylized facts coverage. Note that all the expanded models add more parameters and often random variables to the basic model, yet there are not able to outperform the basic model significantly.

We contribute to the topical literature by inspecting the implications of the financial Ising model towards the capital markets efficiency. We focus on the model parameters and how they influence returns dynamics in the optics of the efficient market hypothesis. The attention is given to finding a combination of parameters which yields an efficient market or dynamics close to it. We thus regard the question “What combination of parameters yields returns and volatility mimicking the stylized facts?” as studied and answered in enough detail in the reviewed papers, implying that the structure and construction of the models are reasonable, and we focus on the question “What combination of parameters yields returns consistent with the efficient market hypothesis?”. We show that the effects of parameters are more complicated than one might expect and their influence is apparently non-linear with a special role of the critical temperature of the system and we discuss the implications for foundations of the efficient market hypothesis.

2. Ising model for financial markets

As a representative of the agent-based models applied to finance and financial economics, we opt for a simple Ising model adjusted for financial markets as proposed by Bornholdt [12]. There are two main reasons why this specific model is chosen. First, the model is able to mimic the most important stylized facts of financial returns. And second, the model has only two parameters which allows for a straightforward interpretation of the outcomes without a need for additional restrictions.