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Speculative bubbles and crashes in stock markets: an interacting-agent model of speculative activity

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Abstract

In this paper, we present an interacting-agent model of speculative activity explaining bubbles and crashes in stock markets. We describe stock markets through an infinite-range Ising model to formulate the tendency of traders getting influenced by the investment attitude of other traders. Bubbles and crashes are understood and described qualitatively and quantitatively in terms of the classical phase transitions. When the interactions among traders become stronger and reach some critical values, a second-order phase transition and critical behavior can be observed, and a bull market phase and a bear market phase appear. When the system stays at the bull market phase, speculative bubbles occur in the stock market. For a certain range of the investment environment (the external field), multistability and hysteresis phenomena are observed. When the investment environment reaches some critical values, the rapid changes (the first-order phase transitions) in the distribution of investment attitude are caused. The phase transition from a bull market phase to a bear market phase is considered as a stock market crash. Furthermore, we estimate the parameters of the model using the actual financial data. As an example of large crashes we analyze Japan crisis (the bubble and the subsequent crash in the Japanese stock market in 1987–1992), and show that the good quality of the fits, as well as the consistency of the parameter values are obtained from Japan crisis. The results of the empirical study demonstrate that Japan crisis can be explained quite naturally by the model that bubbles and crashes have their origin in the collective crowd behavior of many interacting agents.

Keywords: Speculative bubbles; Stock market crash; Phase transition; Mean field approximation; Japan crisis

1. Introduction

The booms and the market crashes in financial markets have been an object of study in economics and a history of economy for a long time. Economists [1] and

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economic historians [2–4] have often suggested the importance of psychological factors and irrational factors in explaining the historical financial euphoria. As Keynes [1], a famous economist and outstandingly successful investor, acutely pointed out in his book, *The General Theory of Employment, Interest and Money*, stock price changes have their origin in the collective crowd behavior of many interacting agents rather than the fundamental values which can be derived from the careful analysis of present conditions and future prospects of firms. In a recent paper published in the Economic Journal, Lux [5] modeled the idea explicitly and proposed a new theoretical model of bubbles and crashes which links market crashes to the phase transitions studied in statistical physics. He explained the emergence of bubbles and crashes as a self-organizing process of infection among heterogeneous traders.[1] In recent independent works, several groups of physicists [7–17] proposed and demonstrated empirically that large stock market crashes, such as the 1929 and the 1987 crashes, are analogous to critical points. They have claimed that the financial crashes can be predicted using the idea of log-periodic oscillations or by other methods inspired by the physics of critical phenomena.[2] In this paper, we present an interacting-agent model of speculative activity explaining bubbles and crashes in stock markets. We describe stock markets through an infinite-range Ising model to formulate the tendency of traders getting influenced by the investment attitude of other traders. Bubbles and crashes are understood and described qualitatively and quantitatively in terms of the classical phase transitions.[3] Although the interacting-agent hypothesis [21] is advocated as an alternative approach to the efficient market hypothesis (or rational expectation hypothesis) [22], little attention has been given to the point how probabilistic rules, that agents switch their investment attitude, are connected with their decision-making or their expectation formations. Our interacting-agent model follows the line of Lux [5], but differs from his work in the respect that we model speculative activity here from a viewpoint of traders' decision-making. The decision-making of interacting-agents will be formalized by the *minimum energy principle*, and the stationary probability distribution on traders' investment attitudes will be derived. Next, the stationary states of the system and the speculative dynamics are analyzed by using the mean field approximation. It is suggested that the mean field approximation can be considered as a mathematical formularization of *Keynes' beauty contest*. There are three basic stationary states in the system: a bull market equilibrium, a bear market equilibrium, and a fundamental equilibrium. We show that the variation of parameters like the bandwagon effect or the investment environment, which corresponds to the external field, can change the size of cluster of traders' investment attitude or make the system jump to another market phase. When the bandwagon effect reaches some critical value, a second-order phase transition and critical behavior can be observed. There is a symmetry breaking at the

[1] For a similar study see also Kaizoji [6].

[2] See also a critical review on this literature [18].

[3] A similar idea has been developed in the Cont–Bouchaud model with an Ising modification [19] from another point of view. For a related study see also Ref. [20]. They study phase transitions in the social Ising models of opinion formation.