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Phase transition phenomenon: A compound measure analysis

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HIGHLIGHTS

- We develop a compound measure to describe the phenomenon of market phase transition.
- The order size is more relevant to phase transition than the investor type.
- Large investors possibly generate phase transition in the KOSPI 200 futures market.

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ABSTRACT

This study investigates the well-documented phenomenon of phase transition in financial markets using combined information from both return and volume changes within short time intervals. We suggest a new measure for the phase transition behaviour of markets, calculated as a return distribution conditional on local variance in volume imbalance, and show that this measure successfully captures phase transition behaviour under various conditions. We analyse the intraday trade and quote dataset from the KOSPI 200 index futures, which includes detailed information on the original order size and the type of each initiating investor. We find that among these two competing factors, the submitted order size yields more explanatory power on the phenomenon of market phase transition than the investor type.

1. Introduction

The phenomenon of phase transition, which indicates discontinuous and dramatic changes in state, is widely discussed in the field of physics. Physicists explain that physical systems exhibit qualitatively different traits across various phases. The source of phase transition in a physical system is the active interaction of its elements as triggered by changes in external conditions. One easily observable example of phase transition in the physical world is the change from solid to liquid and gaseous states: Add enough heat to water, and the water will change from liquid to vapour. Cool water to its freezing point, and it will solidify into ice. In other words, the molecular compound H_2O – the molecules of which actively interact – has three distinct phases depending on external temperature and pressure conditions. Another more specialized example is the concept of phase transition in magnetic systems. Physicists explain the transition of magnetic systems between ordered and disordered phases using statistical and mechanical models, such as the Ising model.

Some innovative statistical physicists apply the concept of phase transition to economic systems. Early discussion of this application occurs in a study by Savit, Manuca, and Riolo [1]. The authors claim that, just as elements in nature interact

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with one another, the agents in economic systems interact and compete. Heterogeneous beliefs among different agents in an economic system imply that their interaction and competition can generate changes in economic phase around critical points. However, this early study does not concretize the concept or characteristics of phase transition behaviour in economic systems. More concrete discussion is carried out in a pioneering piece of research by Plerou et al. [2]. These authors first propose and define an exact concept of a phase transition phenomenon in financial markets. Using the conditional probability distribution of a trading volume measure, they analyse the phase transition behaviour of the New York Stock Exchange (NYSE) in the United States. Their study detects two distinct phases in the NYSE caused by the interaction of market participants that reflect equilibrium and disequilibrium states. This classification fits with the more traditional concepts of stable and fluctuating states in financial markets.

Phase transition behaviour is further analysed in subsequent econophysics studies, which argue that the dynamics of financial markets can be explained using the tools and methodologies of physics. Econophysics studies suggest that even small external shocks can cause dramatic changes in market states when heterogeneous investors in financial markets actively interact. This interaction of discrete factors results in the phenomenon of market phase transition. A study by Zheng et al. [3] examines the phase transition behaviour of the German stock market, arguing that the interacting herding model explains the phenomenon of phase transition in financial markets. The work of Hu et al. [4] also analyses the German stock index and describes the phenomenon of phase transition. These authors explain market phase transition behaviour using a framework of dynamic feedback interaction. Some scholars are sceptical about the phase transition behaviour of financial markets, however, and instead attribute the described instances of phase transition phenomena to the intrinsic nature of volume imbalance distribution [5]. Nonetheless, most studies suggest that phase transition behaviour in financial markets is a significant concept worth interpreting from the perspective of financial economics [6,7]. Kiyono et al. [8] introduce the concept of criticality to explain the phase transition behaviour of the S&P 500 spot market. Drawing on the agent-based spin model, Kim et al. [9] show that financial markets have two distinct phases. Kim et al. [10] examine the phase transition behaviour of various financial markets, including stocks, futures, and options markets. Ryu [11] tries to find the generating force behind phase transition in financial markets and argues that trades initiated by foreign investors are closely related to apparent phase transition behaviour in the KOSPI 200 options market.

In the field of social science, discussions of phase transition behaviour have just begun. One theoretical study by Levy [12] argues that the heterogeneity and conformity of economic agents are key factors for the emergence of phase transition phenomena in social systems. In an extended study, Levy [13] introduces the concept of "social phase transition" and claims that with heterogeneous investors, even a small parameter change in a social system can trigger dramatic variations. Yalamova and McKelvey [14] introduce the framework of behavioural economics to explain the phenomenon of phase transition in financial markets.

This study is motivated by the current situation: existing literature on market phase transition is somewhat piecemeal, despite the active discussions on its significance. To analyse the phase transition behaviour of financial markets, most existing studies adopt a volume imbalance measure similar to the original version proposed by Plerou et al. [2]. A few recent studies assert that phase transition behaviour is still detected when other measures, such as return-based measures (distinct from measures of volume distribution), are used. Those studies explore the applicability of new measures for examining market phase transition behaviour [15,16]. However, even those measures are based on simple and one-sided information from either return or volume aspects of the market. Our central research question is whether we can extract additional information about market phase transition by analysing mixed information based on both returns and volume, which are clearly distinct aspects of the market that remain somewhat interrelated. Therefore, we here propose a new phase transition measure that uses mixed information from volume, returns, and the interaction between the two. Using this compound measure, we try to determine which factor, order size or investor type (each reported as the possible cause of market phase transition), more strongly affects phase transition behaviour in the KOSPI 200 futures market. The KOSPI 200 futures market has little market friction and little asymmetry; consequently, it provides us with an ideal setting for the investigation of our research issues.

Our empirical results show that the phenomenon of market phase transition is readily detected when our proposed phase transition measure is used in the analysis. The results also indicate that information about order sizes provides a better explanation of market phase transition behaviour than information about the types of futures traders. We find that the submission of large orders directly affects phase transition properties in the KOSPI 200 futures market.

The remainder of this study is organized as follows. Section 2 introduces the KOSPI 200 futures market and the sample data and explains why we re-examine the issues of phase transition in the context of the futures market. Section 3 develops the new compound measure to gauge market phase transition. Our major empirical findings and interpretations are presented in Section 4. Section 5 concludes this study.

2. KOSPI 200 futures market and sample data

Since its beginning in 1996, the KOSPI 200 index futures market has grown rapidly, emerging as one of the world's top-tier futures markets. Its trading volume is substantial and comparable to those of the major derivatives markets of developed countries. Indeed, this reflects the high level of interest global investors have in the KOSPI 200 futures market [17–23].

The KOSPI 200 futures market offers an ideal experimental environment to examine phase transition behaviour for several reasons. First, the heterogeneity of market participants and the conformity of futures traders can be important sources of