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The study of Thai stock market across the 2008 financial crisis

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HIGHLIGHTS

- We propose new cohomology theory for financial market.
- We perform analysis of financial tensor network for non-equilibrium state, with closeness centrality of a tensor field of partial correlation, with planar graph of Hilbert–Huang transform with hyperbolic spectrum of IMF.
- We detect the 2008 market crash for Thai SET50 Index Futures market.

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ABSTRACT

The cohomology theory for financial market can allow us to deform Kolmogorov space of time series data over time period with the explicit definition of eight market states in grand unified theory. The anti-de Sitter space induced from a coupling behavior field among traders in case of a financial market crash acts like gravitational field in financial market spacetime. Under this hybrid mathematical superstructure, we redefine a behavior matrix by using Pauli matrix and modified Wilson loop for time series data. We use it to detect the 2008 financial market crash by using a degree of cohomology group of sphere over tensor field in correlation matrix over all possible dominated stocks underlying Thai SET50 Index Futures. The empirical analysis of financial tensor network was performed with the help of empirical mode decomposition and intrinsic time scale decomposition of correlation matrix and the calculation of closeness centrality of planar graph.

1. Introduction

Recent studies [1–5] suggest that financial market is a complex dynamical system with underlying nonlinear and nonstationary financial time series data [6]. When market crashes, the time series data of price of stock will contain with systemic shift and display non-equilibrium entanglement state. The investigation of the 2008 market crash state in nonlinear and nonstationary financial time series data empirically [7,8], is one of the central objectives in the study of a behavior of traders in financial market and it can be useful model to detect future market crash states. In a spacetime of differential geometry, it is possible to use a cohomology group to deform the Kolmogorov space in time series data to detect a dark state in financial market crash. Differential geometry of nonstationary and nonlinear predictor and predictant states in mirror symmetry of time series data is one of the active researches. We assume that a nonstationary state can temporally deform

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the spacetime [9] into a homotopic class of supersymmetry breaking of a supersymmetry of dark states [10]. The market state is decomposed into a coupling state between two linear and stationary states [11]. One of them is an equivalent of the path of a predictor state of time series of observation. The other is a coincident path of an expectation path of dark state for predictant state of forecasting result evaluation in extradimensions of Kolmogorov space in time series data [12].

In Walrasian microeconomics the existence of equilibrium paths in the dynamic economic system requires the equilibrium paths of the complete system to coincide with the equilibrium in economics [13] under linearly and stationary assumption of market state space model or dynamic stochastic general equilibrium [14] with nonstationary state as a noise in financial market [15]. Under this assumption, the Brouwer's fixed-point theorem is used to prove the existence of equilibrium price vector, in which it is not known that the algebraic topological structure underlying market is based on an invariant structure of degree over the covering map between cohomology group of sphere [16].

The economics is a source of definition of the Walrasian utility function in general equilibrium between supply and demand [17] and the topology is concerned with global shape of space and, in particular, its finite or infinite extension [18]. The result of interaction of these two theories in the study of time series in the nonstationary state is so called cohomology theory for financial market [19]. A cohomology theory [20] is a mathematical branch of differential geometry and algebra used to explain anti-de Sitter (AdS) space, it is rich of powerful tools of Cartan calculus of hyperbolic geometry and gauge theory [21,22].

A general equilibrium price in financial market can be realized as cohomology sequence [23] of short exact sequences of Kolmogorov space between Riemannian manifold. A generalization of complex plane of equivalent class of supply and demand curve interacts with Wilson loop of Pauli matrix. It is a spinor field of time series data interpreted as a behavior matrix of traders. Every spinor field of non-orientation state of time series data can be written in the form of quantum triplet state [24] in framework of new cohomology theory for financial market.

The equilibrium price of data recorded from stock market can provide a source of arbitrage opportunity derived from market nonequilibrium state between supply and demand side. After all behavior traders found the opportunity to gain a profit from financial market, the chance will disappear according to efficient market hypothesis (EMH). The orientation of stock Index Futures market is induced from the orientation of quaternionic field in time series data of underlying stocks, in which we can use the average correlation [25] as a standard tool for financial network analysis [26,27]. The ultimate goal of the stock market microstructure prediction [28] is to find an arbitrage change to detect the general equilibrium point of purchasing power parity [29]. It seems that precise definition of a nonstationary state of time series by the projective approach of a hyperbolic space can help to analyze the non-equilibrium state or the crash state in the financial market.

A hyperstructure of non-Euclidean geometry of the behavior of a trader in a financial market [30] can induce a spin structure of principle bundle of a correlation matrix by usage of a cocycle over tangent of Kähler manifold. The underlying financial market of such introduced physical quantity of arbitrage opportunity can be realized as a new complicated topological structure related to the curvature of a spacetime of time series data inside an isometry of group action over tangent of higher topological space of market, such as Lie group of predictor and predictant appearing as an evolution feedback path of expectation market state in the Riemannian manifold. It can be generalized to Kähler manifold or Calabi–Yau manifold, with the complex structure of a metric tensor in which it opens the bridge between Yang–Mill theory and the field of expectation induced by traders behavior to the arbitrage among traders in a financial market. The cohomology sequence of Kolmogorov space of time series data can be induced from a differential 2-form over tangent of Kähler manifold. It is an equivalent class of the path between predictor and predictant topological group. The Lie group structure of a correlation matrix induces its tangent manifold as Lie algebra as space of behavior of traders in financial market with a spinor field of double covering space of Kolmogorov space of time series data. This structure can explain the fix point or equilibrium point in financial market network. In quantum physics, all measurement quantities are associated with Hermitian operator with its eigenvalues. The Hermitian property of a correlation matrix induces an asymmetric property of isometry or inertia frame of reference in space of time series data.

The paper is organized as follows. In Section 2 we introduce the basic definition of a model of trader behavior and new theoretical construction of de Rahm cohomology for financial market. We also define the another form of cohomology group for physiology of time series data so called knot cohomology in time series data. At the end of this section we define an explicit form of eight market states in Kolmogorov space. In Section 3 we perform the empirical analysis of tensor correlation using Hilbert–Huang transform from nonstationary and non-orientation state to stationary and orientation state in time series data before sending the result to the planar graph algorithm to build a financial tensor network. The result of tensor network is used to compute the closeness centrality of hyperbolic angle for the detection of a market crash state in time series data. In Section 4 we show the plots of the results of empirical analysis for daily close price of SET50 Index Futures with average of tensor network of correlation over 42 stocks underlying Index Futures with goal to detect the non-equilibrium state, i.e., the 2008 financial market crash. We use the empirical analysis method of partial correlation matrix as a main tool. In Section 5 we discuss and make a common conclusion about the result of theoretical derivation of cohomology theory and the empirical result of a detection of 2008 financial market crash with tensor network analysis.

2. Cohomology theory in time series data

Let T^n be the n-dimensional torus with $(S^1)^n = S^1 \times S^1 \times \cdots S^1$, the product topology of unit circle into T^n a group structure of space time series data. Let kth homology group $H_k(T^n)$ be a free abelian group of rank C_k^n. We define the Poincare polynomial of a space of time series data X_t as PX_t.

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