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Sector dominance ratio analysis of financial markets

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HIGHLIGHTS

- We present a new measure to investigate the structure of financial markets.
- The evolution of economic sectoral activities can be discerned by eigenvectors.
- The Sector Dominance Ratio that coincides with sharp breaks in asset valuations.
- We propose the Sector Dominance Ratio as an indicator for changes in VIX indexes.

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ABSTRACT

In this paper we present a new measure to investigate the functional structure of financial markets, the Sector Dominance Ratio (SDR). We study the information embedded in raw and partial correlations using random matrix theory (RMT) and examine the evolution of economic sectoral makeup on a yearly and monthly basis for four stock markets, those of the US, UK, Germany and Japan, during the period from January 2000 to December 2010. We investigate the information contained in raw and partial correlations using the sector dominance ratio and its variation over time. The evolution of economic sectoral activities can be discerned through the largest eigenvectors of both raw correlation and partial correlation matrices. We find a characteristic change of the largest eigenvalue from raw and partial correlations and the SDR that coincides with sharp breaks in asset valuations. Finally, we propose the SDR as an indicator for changes in VIX indexes.

1. Introduction

Financial markets are highly complex adaptive systems, resulting from multi-scale interactions amongst individuals, institutions, companies and countries [1]. To better understand the dynamics and structure of financial markets, one can draw on the tools developed in the discipline of complexity science, which has focused on the extraction of useful information for understanding and controlling dynamic interacting systems such as economic, biological, and other complex systems [2–8]. Physics-based approaches also have been proposed for avoiding and controlling systemic risks and crises in financial markets [9,10]. While complex phenomena such as chaos generally lead to unpredictability [11], classical dynamics and quantum statistical mechanics in physics have been applied to many fields of science [12]. Such methods have been successful in analyzing information and conservation laws, and have contributed to the understanding of nonlinear and complex dynamical interacting systems that are not in a state of equilibrium [13–15].

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The network approach also has been used to analyze connections between world financial markets, especially since the coupling between markets has strengthened in recent years [16]. The evolution of dependencies in the global market can be quantified by constructing the dependency network for each market [17]. At a smaller scale, the network structure of markets and the interactions and dependencies among economic sectors within national markets also can be modeled using such a structure [18]. The structure of economic sectors within each market is relevant not only to intramarket properties, but also affects the relation across markets. In addition, each market has a unique structure of economic sectors; for example, the energy and financial sectors are of relatively high importance in the US stock market. Uncovering which economic sectors play a dominant role in each market is fundamental to understanding their structure.

Many methods have been applied to studying information embedded in the interactions in stock markets. One key statistically based approach is the use of empirical correlation analysis, and the analysis of empirical correlations between different financial assets [19–21]. A major contribution of statistical physics to these efforts has been the use of Random Matrix Theory (RMT) to uncover latent information embedded in the observed empirical correlations [22–30]. RMT is a methodology to evaluate the eigenvalues of empirical correlation matrices, originally developed in the field of nuclear physics by Wigner and Dirac to explain energy levels of complex quantum systems.

In their seminal work, Plerou et al. [22] tested the eigenvalue statistics of the empirically measured correlation matrix C, of historical returns from the US stock market against the null hypothesis of a random correlation matrix. This allowed them to distinguish genuine correlations from spurious correlations that are present even in random matrices. They found that the bulk of the eigenvalue spectrum of C shares universal properties with the Gaussian orthogonal ensemble of random matrices. Further, by analyzing deviations from RMT, they showed that the largest eigenvalue and its corresponding eigenvector represent the influence of the entire market on all stocks; using the remaining deviating eigenvectors, they were able to partition stocks into distinct subsets whose identity corresponds to conventionally identified economic sectors. Finally, they introduced an approach which utilizes these results for the construction of portfolios that have a stable ratio of risk to return.

Recently, Kinlaw et al. [31] introduced a method to measure systemic importance using the absorption ratio and variance of eigenvectors introduced by Ref. [32], which is equal to the fraction of a market's total variance explained by a subset of important factors. This method provides the possibility to assess whether a market is fragile or resilient to shocks or external effects by examining the value of the absorption ratio. Furthermore, this tool was extended to measure the centrality of an economic sector in a given market, by the use of a centrality score.

In this paper we propose to extend previous work by introducing a new approach to uncover the functional dominance of economic sectors, using RMT. We propose a new indicator, the Sector Dominance Ratio (SDR), to examine economic sectoral makeup at a certain reference time interval using both raw correlation and partial correlation matrices. Here we term standard Pearson correlation coefficients [33] as raw correlations. Partial correlations are the correlation between two variables after removing the mediating effect of a third variable (see Methods section), and provides the means to uncover the nature of the hidden embedded relationships between different sectors of the market. We will introduce the SDR methodology and study the dynamic changes of SDR employing eigenvectors obtained from both raw and partial correlation matrices. The SDR uses RMT to identify the informative components of the empirical correlation matrices, and thus, unlike other factor models or principal components-based indicators, does not require making assumptions on where the meaningful system information is embedded. As such, the SDR can shed additional light into the functional structure of financial markets.

We examine the SDR for both yearly and monthly bases for raw correlation and partial correlation matrices. We apply the SDR methodology to study the structure of four different stock markets, those of the US, UK, Germany, and Japan, and investigate whether the economic sectoral makeup is indeed apparent in the observed prices and their evolution over time. The information obtained from the model of SDR provides important insights into the underlying driving forces in the dynamics of real stock markets: not only the importance of each sector, but also the state of the sector and whether its activity or growth rate is increasing or decreasing. Finally, we show the SDR is useful for predicting the behavior of VIX indexes using a Granger causality and cross correlation tests for both raw and partial correlations.

The paper is organized as follows. Section 2 refers to methods for the analysis of stock market data, correlation coefficients and the introduction of the RMT approach as well as the relation between RMT and the factor model. In Section 3, we present the formal model of the SDR using components of eigenvectors for raw and partial correlations. In Section 4, we examine the distribution of eigenvalues and the components of the largest and second largest eigenvector. We present the results obtained from the SDR analysis in Section 5 focusing on the sectoral content of the different markets in different time periods. We show that the method of raw and partial correlations and the model of SDR provide important information on the underlying structure of financial markets and their dynamics. Finally, we discuss the main results and conclusions in Section 7.

2. Materials and methods

2.1. Data

We employ the daily adjusted closing price from four major stock markets (see Ref. [16]) downloaded from Thomson Reuters Datastream. For the US, the UK and Japan, we include stocks belonging to each country's most important stock