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Correlation of financial markets in times of crisis

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ABSTRACT

Using the eigenvalues and eigenvectors of correlations matrices of some of the main financial market indices in the world, we show that high volatility of markets is directly linked with strong correlations between them. This means that markets tend to behave as one during great crashes. In order to do so, we investigate financial market crises that occurred in the years 1987 (Black Monday), 1998 (Russian crisis), 2001 (Burst of the dot-com bubble and September 11), and 2008 (Subprime Mortgage Crisis), which mark some of the largest downturns of financial markets in the last three decades.

1. Introduction

The study of why many world financial markets crash simultaneously is of central importance, particularly after the recent worldwide downturn of the major markets in 2007 and 2008. Economists have been studying the reasons why markets crash, and why there is propagation of volatility from one market to another, since a long time. After the crash of 1987, many studies have been published on transmission of volatility (contagion) between markets using econometric models [1–15], on how the correlation between world markets change with time [16–19], and how correlation tends to increase in times of high volatility [20–34]. This issue is of particular importance if one wishes to build portfolios of international assets which can withstand times of crisis [35–47]. Many models were proposed by both economists and physicists in order to explain the correlation of international financial markets [48–66], which is considered a complex system with many relations which are difficult to identify and quantify.

One tool that was first developed in nuclear physics for studying complex systems with unknown correlation structure is random matrix theory [67–70], which confronts the results obtained for the eigenvalues of the correlation matrix of a real system with those of the correlation matrix obtained from a pure random matrix. This approach was successfully applied to a large number of financial markets [71–100], and also to the relation between world markets [101,102]. This approach was also used in the construction of hierarchical structures between different assets of financial markets [103–141].

Recently, time lagged random matrix theory was used in order to compute long-range cross-correlations of world stock indices [142], showing that the correlations of absolute returns decay much more slowly than the correlations of returns. In Ref. [143], the same results were reported for absolute values of returns between the Dow Jones and the S&P indices of the New York Stock Exchange. In Ref. [144], pronounced peaks were reported during the largest world market crashes of the last few decades. Cross-correlations between volume change and price change was studied in Ref. [145]. Other studies using cross-correlations were also done in Refs. [146–148].

Recent methods for studying random matrices obtained from non-Gaussian distributions, such as t-Student distributions, which represent more closely the probability density distributions obtained from financial data, were developed in Refs. [149–152]. Other studies focus on other measures of co-movement of financial indices that are more appropriate for systems with very strong correlations, as happens in times of financial crises [153,154].

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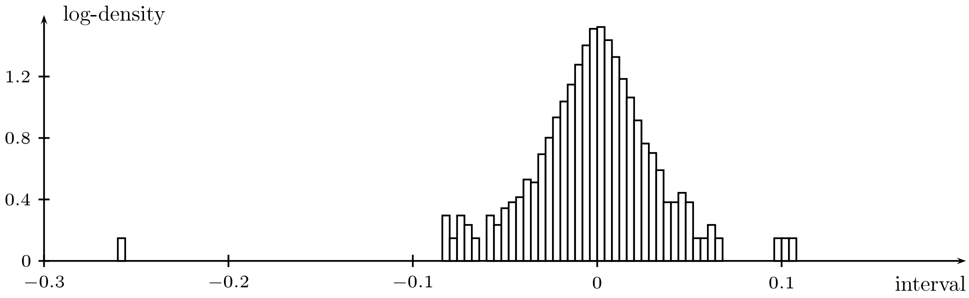

Fig. 1. Log-density distribution of the Dow Jones index of the NYSE, from 01/02/1985 to 12/31/2008.

Our work uses the tools of random matrix theory to analyze the correlation of world financial markets in times of crisis. In order to do so, we use data from some of the largest worldwide crashes since 1980, namely the 1987 Black Monday, the 1998 Russian Crisis, the burst of the dot-com bubble of 2001, the shock after September, 11, 2001, and the USA subprime mortgage crisis of 2008. We start by defining a global financial crisis (Section 2) based on evidence of some financial markets chosen from diverse parts of the world. Then, we discuss some of the main theoretical results on Random Matrix Theory (Section 3). Then, in Section 4, we make a quick discussion on how we collected the data and how it was treated.

In Sections 5–8 we study the correlation matrices between the log-returns of a number of financial market indices chosen so as to represent many geographical parts of the world and a diversity of economies. In each section, we calculate the eigenvalues of the correlation matrix of the chosen indices and then study the eigenvector that corresponds to its largest eigenvalue, which is usually related with a *market mode*, which is a co-movement of all indices. We then calculate correlation matrices in running windows and compare the average correlation between markets with the volatility and average volatility of the market mode obtained previously, showing that times of large volatility are strongly linked with strong correlations between world financial indices.

Section 9 looks more closely at the probability distribution of the correlation coefficients in different intervals of time and tests the hypothesis that it becomes closer to a Gaussian probability distribution during periods of crises.

Since the study of world stock exchanges involve dealing with different operating times, in Section 10 we compare the results obtained in the previous sections with results obtained by using the log-returns of Western markets with the log-returns of the next day in Asian markets. We also compare the results obtained in the main text of the article with those obtained by using Spearman's rank correlation instead of Pearson's correlation.

Since world stock market indices (countries) are easier to relate with than equities in a stock market (companies), one of the aims of this article is to be a pedagogical introduction to most of the techniques that are used when Random Matrix Theory is applied to financial data. Hence we also supply an ample bibliography on the subject.

2. Defining a global financial crisis

Before studying periods of financial crises, we must make it clear what we consider to be a global crash of the financial markets. In order to adopt a more precise definition, we considered the time series of 15 financial markets representing different regions of the world from the beginning of 1985 until the end of 2010. Looking at the closing indices of every day in which there was negotiation, we considered the log-returns, given by

$$S_t = \ln(P_t) - \ln(P_{t-1}) \approx \frac{P_t - P_{t-1}}{P_t}, \tag{1}$$

what makes it easier to compare the variations of the many indices. After that, the 10 most negative variations were chosen.

In order to illustrate the procedure, we consider the Dow Jones index of the New York Stock Exchange (NYSE). Fig. 1 shows the log-density distribution for this index with data from 01/02/1985 to 12/31/2008. The log-density, defined as

$$\text{log-density} = \ln(1 + \text{density}), \tag{2}$$

is used instead of simple density in order to better visualize the most extreme points.

The ten most negative values of the log-returns are below −0.07. These events occurred in the following occasions: 10/19/1987 (22.61%), 10/26/1987 (8.04%), 01/08/1988 (6.85%), 10/13/1989 (6.90%), 10/27/1997 (7.18%), 09/17/2001 (7.13%), 09/29/2008 (6.98%), 10/09/2008 (7.33%), 10/15/2008 (7.87%), and 12/01/2008 (7.70%). These dates include the 1987 Black Monday, part of the Asian Crisis of 1997, the 1998 Russian Crisis, the aftermath of September 11, 2001, and the Subprime Mortgage Crisis of 2008.

The same technique was used for the Nasdaq (USA), S&P/TSX Composite (Canada), Ibovespa (Brazil), FTSE 100 (UK), DAX (Germany), ISEQ (Ireland), AEX (Netherlands), SENSEX 30 (India), Colombo All-Share (Sri Lanka), Nikkei (Japan), Hang Seng (Hong Kong), TAIEX (Taiwan), Kospi (South Korea), Kuala Lumpur Composite (Malaysia), and Jakarta Composite (Indonesia).