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TROUBLE AHEAD

- The Subprime Crisis as Evidence of a New Regime in the Stock Market

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In August 2007, the crisis of the subprime mortgage industry stormed the financial systems of several countries. As a response, hundreds of billions of dollars were injected by the authorities into the market. Nevertheless, this was not enough to avoid the second wave of the subprime crisis, as revealed by the fall of the S&P500 stock index since January 2008. In spite of the important achievements obtained in finance theory, the conventional wisdom on the inexistence of structure in the evolution of stock markets still prevails. The Efficient Market Hypothesis view ([1],[2]) assesses the evolution of financial markets as the result of a Brownian process. More recently, the contributions of econophysicists ([3],[4],[5]) have challenged the dominance of randomness. Using a stochastic geometry technique, here we show that the dynamics of the S&P500 set of stocks defines a structure, which is specifically shaped by the occurrence of crises. A new coefficient is defined in order to capture the structural changes occurring on the S&P500 set of stocks.

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This coefficient highlights an important modification of the dynamics of the 253 firms represented in the S&P500 and acting in the market for the period August 1988-January 2008, and situates the turbulence since the Summer 2007 as replica of a larger structural change going on for a decade.

In order to identify the structure in the market we proceed as follows. Define p_t as the price of a given stock and the stock price return r_t as the daily change of the logarithm of stock price, $r_t = \ln(p_t) - \ln(p_{t-1})$. Pick the representative set of N stocks and their historical data of returns over a time interval (window). From the returns data, compute the matrix of distances between the N stocks (as in references [3] and [4]).

$$d_{kl} = \sqrt{2(1 - C_{kl})} \quad (1)$$

being C_{kl} the correlation coefficient of the returns. From the matrix of distances, compute coordinates for the stocks in an Euclidean space of dimension $N - 1$. The stocks are now represented by a set $\{x_i\}$ of points in R^{N-1} . To this cloud of points apply the standard analysis of reduction of their coordinates to the center of mass and the computation of the eigenvectors of the inertial tensor. The directions for which the eigenvalues are significantly different from those obtained applying the same technique to surrogate data (as obtained by independent time permutation for each stock) are identified as the market systematic variables. The number of systematic variables define the effective dimensions of the market space (as in [6], [7]).

It was empirically found that markets of different sizes, ranging from 70 to 424 stocks, across different time windows (from one year to 35 years) and also from different market indexes¹ have only six effective dimensions. These six-dimensional spaces define the reduced subspaces which carry the systematic information related to the correlation structures of the markets. These dimensions capture the structure of the deterministic correlations and economic trends that are driving the market, whereas the remainder of the market space may be considered as being generated by random fluctuations. Moreover, the application of our stochastic geometry technique over time windows of one year ($w = 250$) shows that the quite 'universal' six-dimensional reduction also holds for turbulent and normal periods. Both the years including the most extreme events and the years where 'business as usual' prevails fit into a six-dimensional space.

¹stocks from the S&P500 and Dow Jones indexes were considered

However, observing the evolution of the S&P500 market space along its leading effective dimensions, important differences appeared in the market shape (Fig.1). The most remarkable differences depend on whether the yearly period corresponds to a normal or to a turbulent period. If the yearly period contains relevant crashes, the geometric object defining the dynamics of the market is distorted, acquiring prominences in some particular directions. The index S ([7], [8]) computes that distortion effect, namely, the lack of uniformity along the S&P500 six effective dimensions.

$$S_t = \sum_{i=1}^6 \frac{\lambda_t(i) - \lambda'_t(i)}{\lambda'_t(i)} = \sum_{i=1}^6 \frac{\lambda_t(i)}{\lambda'_t(i)} - 1 \quad (2)$$

where $\lambda_t(1), \lambda_t(2), \dots, \lambda_t(6)$ are the six largest eigenvalues of the market space and $\lambda'_t(1), \lambda'_t(2), \dots, \lambda'_t(6)$ are the largest six eigenvalues obtained from surrogate data. In computing S , at a given time t , both λ_t and λ'_t are obtained over the same time window and for the same set of stocks. Looking for relevant distortions in the shape of the S&P500 market space through the last 20 years, we found that amongst the highest values of the index S are those computed for some important dates, as October 1997 and September 2001, as Fig.2 shows.

But if the geometric object defined by the dynamics of the market is distorted whenever a crisis occurs, it may be caused by groups of stock that evolve in strong synchronicity. To characterize this additional information on the structure of the market spaces, here we define the coefficient R , which quantifies the distribution of the correlation strengths between stocks present in the S&P500 market space along the last 20 years.

From the matrix of distances between stocks (equation 1) computed in the reduced six dimensional space (D^6) over a time window of 22 days, we apply the hierarchical clustering process to construct the minimal spanning tree (MST) that connects the N securities. Then the boolean graph B_{D^6} is defined by setting $b(i, j) = 1$ if $d^6(i, j) \leq L_{D^6}$ and $b(i, j) = 0$ if $d^6(i, j) > L_{D^6}$, where L_{D^6} is the smallest threshold distance value $d^6(i, j)$ that insures connectivity of the whole network in the hierarchical clustering process. This allows for defining the coefficient R , which captures the relative distribution of the distance values below and above the smallest threshold distance value (L_{D^6}) that insures connectivity of the whole network.

$$R_t = \frac{\sum_{d_t^6(i,j) \leq L_{D^6}} d_t^6(i,j)}{\sum_{d_t^6(i,j) > L_{D^6}} d_t^6(i,j)} \quad (3)$$

Results (Fig.3) show that the amount of strong correlated (short-distant) fluctuations in the network of stocks is very large for some particular crises (1997 second Black Monday, 2003 general recession and 2007-2008 Subprime Crisis). These networks display a large amount of distances whose values are below the endogenous threshold value. This is due to the emergence of a relevant set of highly correlated fluctuations of the stock returns during market shocks forcing several *weak* correlated fluctuations to leave this category. Although the values of the overall network distances decrease with crashes, the emergence of highly correlated groups of stocks occupying the prominences in the market distorted shape, leads to an increase of the value of the endogenous threshold L_{D^6} . As a consequence, the number of distances below L_{D^6} tend to be much higher than the number of those that remain above the endogenous threshold, leading to a significant increase of the values of R .

During the Subprime Crisis, R reaches 1.4 (Fig.3), while the same coefficient computed for normal periods rests below 0.5 (computing R from surrogate data yields typical values around 0.025). The evolution of R confirm our previous results, identifying the major crashes in the period and detecting how peculiar it is the Winter 2008 crisis. The Subprime Crisis constitutes the highest peaks in the evolution of R for the period under consideration. The results reveal that a major change is occurring for the last decade, imposing a new dynamic structure marked by frequent crashes. As Fig.2 shows, the crashes concentrate in the period after 1997. This difference in the empirically described evolution suggests that in the period of the easy interest rates, the 'Internet boom' and the housing bubble, a new regime was generated, giving birth to a new phase of turbulence in the financial markets. Distortion effects occurring on the market effective dimensions provide useful insight on the structure of the markets as it is revealed under shocks. Here we show that the characterization of the distribution of the correlation strengths between stocks provides additional informational on the mutation in the structure of the market, suggesting that the prominences emerging in the market shape during crisis correspond to groups of companies that move following sectoral dynamics, in an even stronger synchronization.

The results shed a new light on the subprime crisis since August 2007 through the Winter 2008, and suggests that it is not a simple speculative shock. As the data and the stochastic geometry suggest, this ongoing turbulence is part of a mutation in the structure of the market since around 1997. The new structure has generated deeper and more frequent episodes of crises. The trouble is ahead.

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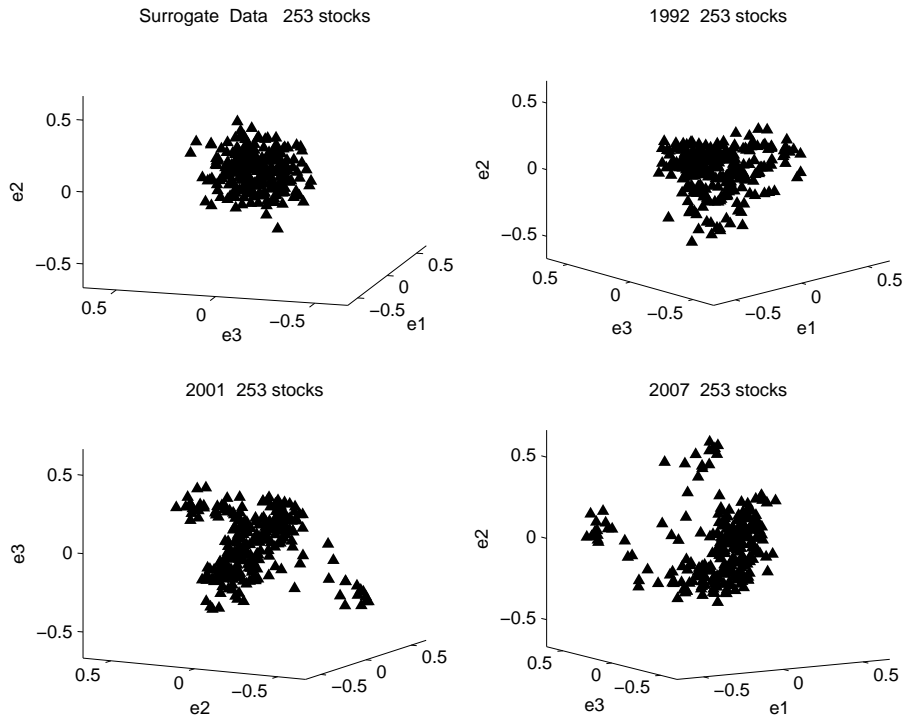


Figure 1: The evolution of the stock market for one year (or for a random permutation of data). The first two plots show the spherical configuration of both surrogate (time permuted) and a year of 'business as usual' data, whereas the last two plots show the distorted shapes of the same market space in years of turbulence. While in 1992 there is no relevant difference in relation to time permuted data, in 2001 and 2007 a new shape emerges.

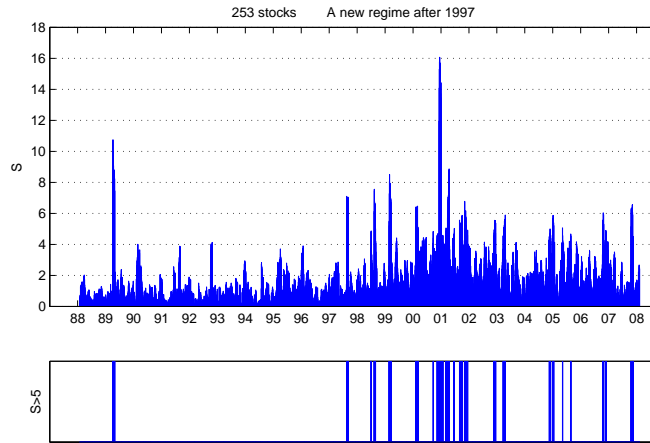


Figure 2: The evolution of the structure index S - using a moving window of one month of daily returns ($w = 22$) - corresponds to the evidence that, during financial crises, the geometric object describing the stock market is distorted along definite directions.

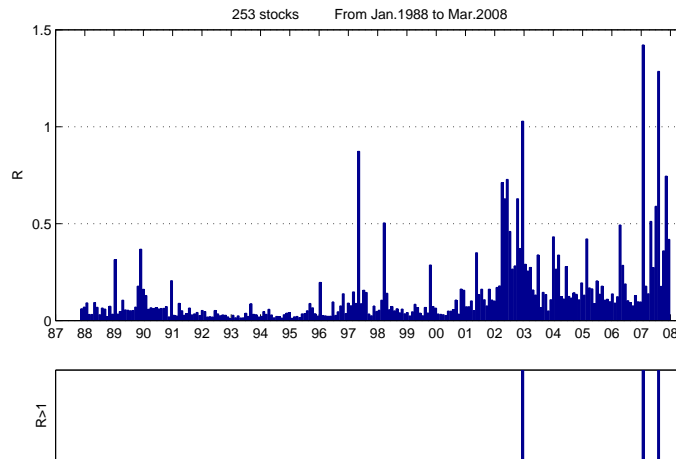


Figure 3: The evolution of the coefficient R (with $w = 22$) captures the emergence of highly correlated groups of stocks and detects how peculiar it is the Winter 2008 crisis.