



Volatility and correlation-based systemic risk measures in the US market[☆]



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HIGHLIGHTS

- This paper tests some systemic risk measures based on correlation matrices using Granger-causation of the S&P 500 and the VIX indexes.
- This paper deepens the discussion around eigenvalue entropies in Finance, showing some theoretical considerations about the impact of negative correlations.
- The indicators are shown to Granger-cause the S&P 500 in all windows observed, but they do not necessarily Granger-cause the VIX.
- Their impact on the returns is highly dependent on the selected window.

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ABSTRACT

This paper deals with the problem of how to use simple systemic risk measures to assess portfolio risk characteristics. Using three simple examples taken from previous literature, one based on raw and partial correlations, another based on the eigenvalue decomposition of the covariance matrix and the last one based on an eigenvalue entropy, a Granger-causation analysis revealed some of them are not always a good measure of risk in the S&P 500 and in the VIX. The measures selected do not Granger-cause the VIX index in all windows selected; therefore, in the sense of risk as volatility, the indicators are not always suitable. Nevertheless, their results towards returns are similar to previous works that accept them. A deeper analysis has shown that any symmetric measure based on eigenvalue decomposition of correlation matrices, however, is not useful as a measure of “correlation” risk. The empirical counterpart analysis of this proposition stated that negative correlations are usually small and, therefore, do not heavily distort the behavior of the indicator.

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1. Introduction

“You know something is happening here, but you do not know what it is”. This Bob Dylan’s phrase summarizes the promise of financial indicators discussed in the post-2008 financial crisis. There are plenty of new measures [1–5] showing new patterns we have not noticed before the crisis. While it is wonderful that we have a lot of mechanisms to perceive shocks in markets, it is dangerous that some of these instruments we trust have measurement sensitivities – as, for instance, to work just in restricted time windows – that were not discussed in previous literature.

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The instruments studied here, Systemic Risk measures based on correlations of returns, are important as they are quite simple to use to access financial turbulences. They are a class of market indicators that are highly known in the econophysics literature [6–10]. Recent econometric literature, reviewed by the influential survey of Bisias et al. [11], has several subrends. The measures related to the theme of this paper are the ones that may be computed using just price time series, as the network analysis proposed by Refs. [12,13] and analysis based on dynamics of correlation [14]. Other measures accessing tail-risk origins present in [11] use considerably more data. Along with this empirical literature, economic theory based on insurance and economic stability under network arrangements is discussed in [15–17], with results related to contagion of crisis under several kinds of shocks.

Based on these observations, this paper is devoted to understand whether or not the properties of some systemic risk indicators based on correlation matrices are useful to correctly analyze financial markets. The main indicators studied here are the Absorption Ratio [5], Eigenvalue Entropy [18] and Index Cohesion Force [2,19]. The reason to study Absorption Ratio is simply the fact that it is the eigenvalue-based measure constructed using returns series mentioned in [11]; the other indices were included based on their previous results and building process. Some other metrics, as Mahalanobis Distance [4] and network based measures, were not included because they, in their actual presentation, are not directly applicable to Granger-causality. There is also the sector dominance ratio defined by Ref. [20] that performed a similar Granger-causation analysis about sector dominance in the VIX index, with a positive result. The three systemic risk measures studied here are representatives from three categories: one directly using the correlation matrices, the second using eigenvalues based on the covariance matrix and the third one based on the eigenvalues of the correlation matrix. Special attention is devoted to Eigenvalue Entropies due to its origins in biology [21,22], not finance. The impacts on returns – measured as the S&P 500 daily returns – and on volatility – the VIX index – are studied in this paper. The context of applying a linear Granger-causality test to this financial data is to provide an initial test of the validity of the indicators for forecasting or financial managerial applications. The results provided, for instance, towards Index Cohesion Force, are a useful alert about some sensitivities of the indicator: it must be estimated using longer series and must not be used to forecast risk in the sense it is measured by the VIX, the “fear index”. The same applies to Absorption Ratio. The managerial applications of it may be related to when to consider the indicators for asset allocations or choosing risk management tools.

We state Eigenvalue Entropy has conceptual problems that, theoretically, can affect its behavior. Moreover, we extend these limitations to any symmetric function based purely on Eigenvalues of correlations between assets: they fail to incorporate the effects of negative correlations between assets on systemic risk. This analysis is based on the derivatives matrix of eigenvalues. They are shown to be non-injective and, therefore, there cannot exist any symmetric spectral function that grows monotonically with the assets correlation. There is no theoretical reason to think this measure can be useful to explore the correlations, however it can be used to measure other properties of financial markets. This, however, does not eliminate the potential use of eigenvalues through other techniques, such as Random Matrix Theory [23–26] and, as an empirical test may show, the application of the indicator in returns and volatility forecasting.

Because of that theoretical gap, the Granger-causality of Shannon Eigenvalue Entropy to Financial Markets returns [18] is revisited. Moreover, a recent empirical application has shown some limitations of the indicator related to time-sensitivities [27]. The analysis based on Granger-causation is well developed for several applications in finance [20,28–30]. Using a classification of typical markets and collapse prone markets [19], we show this evidence is less robust than expected for Index Cohesion Force and Absorption Ratio indicators. Moreover, results that allow to analyze how much the estimation window affects the returns are presented in this paper. It is possible to see the results are sensitive to the estimated window, as, for instance, the largest eigenvalue varies strongly according to the window size. This paper shows the Eigenvalue Entropy changed the need for data – measured by estimation windows – before and after 2003. The eigenvalue entropy from 2003 to 2013 was significant at 5% for most window sizes tested, but its delta usually performed better, especially from 1997 to 2002. This evidence shows the eigenvalue entropy indicator is reliable empirically for Granger-causing the returns in this case.

However, a similar test of Granger-causation of Eigenvalue Entropy and the VIX index – an indicator of implicit volatility of the S&P 500 – was significant for just the Eigenvalue Entropy before 2002. Based on the definition of risk as volatility, this is a flaw. The data used on the experiments of the paper was all stock prices – 346 firms – from the S&P 500 (collected August 31st 2014) from 1994 to 2013 available at Yahoo! Finance. These series were broken around 2002 following the recommendations of Ref. [19] to verify if there is a difference on how the indicators work. In the light of these results, it is clear that systemic risk measures may be useful, but some care on how to apply them is necessary.

A brief discussion of the methods used is Section 2. Section 3 is devoted to the Index Cohesion Force and the fourth exhibits a brief analysis of the Absorption Ratio. These sections present a Granger-analysis of the indicators towards returns and implied volatility. This test is also present in Section 5, devoted to the application of the Eigenvalue Entropy on financial markets. Section 6 briefly discusses empirical correlations of the indicators. Finally, there is the conclusion with suggestions of robustness tests for empirical utilization of simple systemic risk variables.

2. Methods

In this section, I discuss the methods used in the paper. Mainly, the systemic risk measures related are correlation-based. In other words, the instruments are built using simple correlations between several assets. The Pearson correlation – the

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