Communicability Reveals Crisis-Specific Structural Reorganization in Financial Networks

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Extended Abstract

Motivation. Financial markets can be viewed as complex systems where stocks interact with each other. During crisis periods, these interactions often become stronger, and many stocks begin to move together. Previous studies show that networks built from stock correlations become more interconnected during turbulent times, and several standard network measures have been used to examine these changes. Most of these measures, however, are based on shortest paths and therefore assume that information moves only through the most direct links. In real markets, interactions can spread through many indirect routes. Communicability accounts for this by considering all possible walks between pairs of nodes using the matrix exponential of the adjacency matrix. In this study, we examine whether communicability can capture structural changes in financial networks during crises more effectively, and whether different crises leave distinct patterns of connectivity in the network.

Approach and Methodology. Our dataset comprises daily log returns for stocks in the NIFTY 500 index for two major financial events: the 2008 global crisis and the 2020 COVID-19 pandemic, an unprecedented crisis. For each period, correlation matrices are calculated using 60-day rolling windows. These matrices are then filtered using the Planar Maximally Filtered Graph (PMFG) to retain the most important connections while preserving the network's structure. From each network, we compute edge betweenness centrality, shortest path length, and communicability. To compare stable and volatile periods, we calculate the shortest communicability path lengths and use permutation testing to check whether the observed differences are statistically significant. Finally, we test whether these measures can distinguish stable and volatile periods using a linear support vector machine with nested cross-validation and recursive feature elimination [1, 2, 3].

Results. The analysis reveals noticeable changes in the structure of the financial network during crisis periods. Our results show that approximately 70% and 80% of stock pairs exhibit statistically significant changes in communicability during the global financial crisis and the unprecedented COVID-19 crisis, respectively, at the 0.001 significance level. The observed shifts in shortest communicability path lengths offer directional cues about the nature and depth of each crisis. Furthermore, when used as features in machine learning classification models, communicability measures outperform the shortest-path-based measures in distinguishing between market stability and volatility periods.

Conclusions and Outlook. This study shows that communicability provides a sensitive and structurally informative measure of financial network reorganization during crises. Importantly, different crises produce qualitatively different patterns of connectivity change. Ongoing work extends this framework toward real-time monitoring using rolling-window detection and cross-market validation.

Figure 1: (a) Heat map of the difference between the averaged shortest communicability path length, and (b) Heat map of the difference between the averaged shortest path length during stability and volatility periods, shown on the same scale as (a). figures are generated over unweighted network corresponding to the two periods (2005 and 2008).

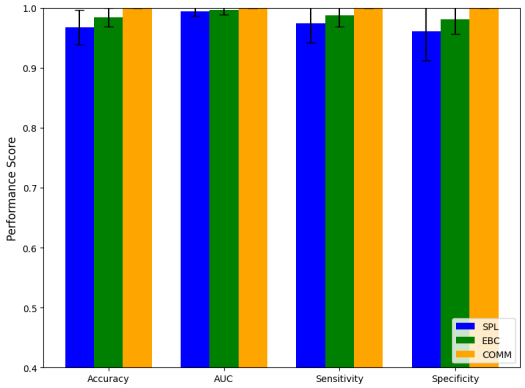

Figure 2: Performance overview of all the connectivity measures, stable and volatile periods classification corresponding to the pandemic crisis of the year 2008.

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