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Information Processing Pathways in the Stock Markets

Keywords: Complex systems, Stock markets, Information flow, High-temporal resolution, Alluvial diagram

Extended Abstract

Motivation: Stock markets are known to behave like complex systems, showing features such as self-organization and emergence. Visualization tools from Network Science allow us to have a high spatial resolution of stock market structures, but there is a lack of focus on high-temporal studies of the stock markets. In this talk, we will bridge the research gap by demonstrating the self-organization of persistent structures in stock markets at high temporal resolution. This topic is important for financial regulators and the public, as market crashes can occur in a short period of time, and insights obtained from understanding its dynamics can help us prevent future financial bubbles and crises.

Approach: To obtain information from the stock markets on multiple time scales, we apply a newly derived technique known as 'quasi-differentiation' (QD) to obtain high temporal resolution cross-correlation measures of stock pairs on a daily basis [1]. The window widths used to compute cross-correlation of stock pairs in the QD process vary from ten trading days to nearly the entire trading year, allowing information to cross-filter at multiple time scales. To select the appropriate time scales, we began by plotting the daily closing prices and returns of several stock pairs of interest such as Microsoft (MSFT) - Exxon Mobil (XOM) (**Figure 1a**) and performed QD over a range of window widths from 20 to 250 days. We showed the results in a heat map to identify time scales (w) of interest, which we determined to be around 35, 70, 120, and 180 trading days (**Figure 1b**). Next, we integrated the QD results for all stock pairs of the S&P 500 at the selected time scales to obtain their cross-correlation values (**Figure 1c**). We then performed Topological Data Analysis (TDA) and Ricci Curvature Analysis (RCA) to obtain topological and geometric information on the stock markets at multiple length scales [2]. This is done by means of filtration, that is, varying the cross-correlation thresholds of stock pairs in the markets at different values and connecting a pair of stocks if and only if their cross-correlations are higher than the threshold. RCA also informs us about the number of connected components, the number of holes and voids in the network [3]. Finally, the TDA process is repeated for the correlations of all time scales obtained from the QD analysis earlier, and the final result will be shown in alluvial diagrams (**Figure 1d**).

Results: We have obtained a 40-day alluvial diagram of S&P 500 constituents on a timescale $w = 35$ days for a key period during the first US-China Trade War around late September-October 2019. The diagram depicted clusters in the markets underwent reorganization (e.g., fusion and fission) in the form of cascades over time, with the fission process dominating towards the end of October after the first phase of the US-China trade deal was signed. The number of stocks in the largest two clusters, consisting of mainly "growth" stocks and "value" stocks, respectively, decline over time as the parent clusters fragmented towards the 1st October tariff deadline into smaller child clusters whose stocks belong to the various domestic industries expected to benefit with the new tariff policy implemented.

Outlook: We expect to generate 70-day, 120-day and 180-day alluvial diagrams and compare them among different length scales. We also expect to extend our study to the March 2020 COVID-19 pandemic market crash, which is a much more dramatic event, with the goal of discovering the duration of the cascades and the cross-sectional stock pairs involved in the cascades to better understand the crash nature of the market.

References

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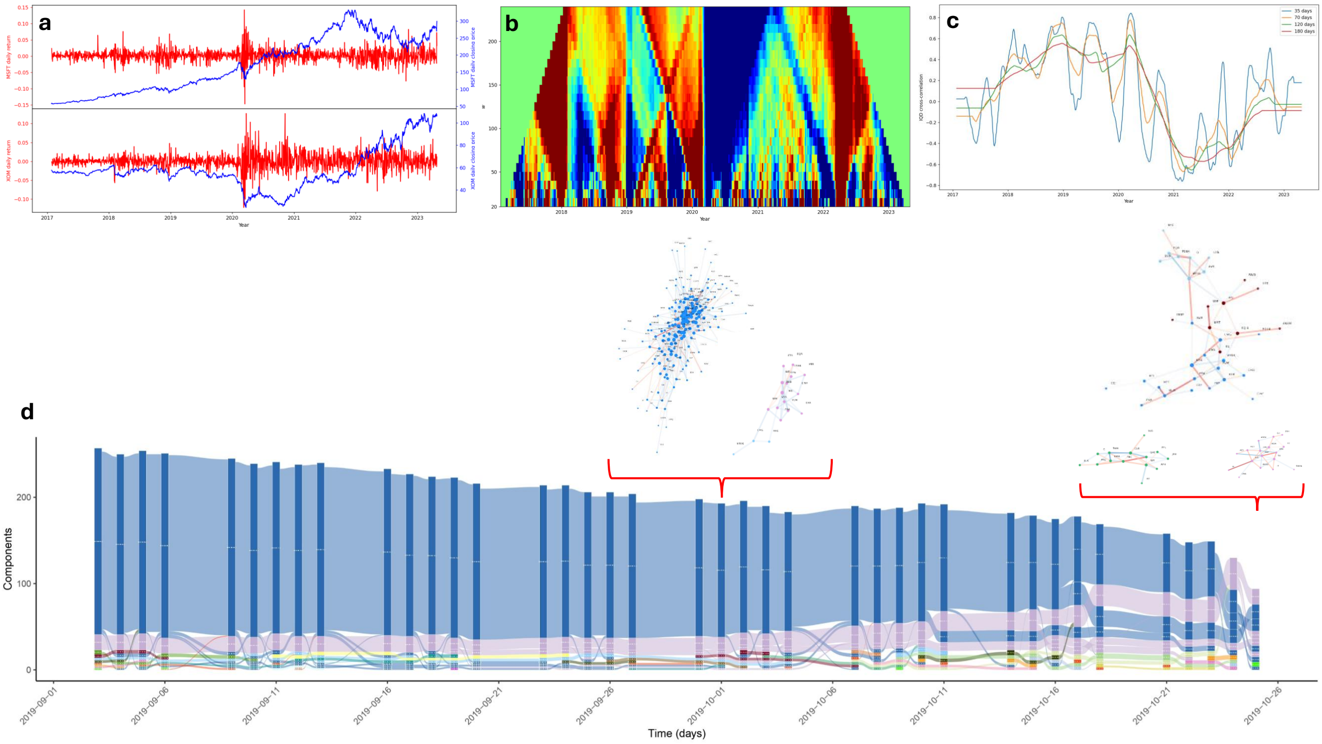

Figure 1: **Illustrating the Multiple Time and Length Scale Study using MSFT-XOM stock correlation as example** *a)* The daily prices and daily returns of Microsoft (NASDAQ: MSFT) stock and Exxon-Mobil (NYSE: XOM) stock from 26th January 2017 to 28th April 2023 are shown. *b)* We perform quasi-differentiation technique to obtain the rate of change of cross-correlation between MSFT-XOM stock pair across the same time period as in *a)* using different window widths of 20 to 250 days, at an increment of 10 days. *c)* We integrate results from *b)* for selected window widths $w = 35$, 70, 120 and 180 days to observe for changes in correlations between MSFT and XOM across time. *d)* Procedures *a)-c)* are repeated across the entire S&P 500 constituents with $w = 35$ days to obtain an alluvial diagram of stock clusters with high temporal resolution. Multiple splitting and merging events between stock clusters can be seen leading to the first US-China Trade War around 1st of October 2019. We also show above the alluvial diagram the fragmentation of stock clusters towards the end of October (25th of October 2019).