The Spread of the Credit Crisis: View from a Stock Correlation Network

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The credit crisis roiling the world's financial markets will likely take years and entire careers to fully understand and analyze. A short empirical investigation of the current trends, however, demonstrates that the losses in certain markets, in this case the US equity markets, follow a cascade or epidemic flow like model along the correlations of various stocks. This phenomenon will be shown by the graphical display of stock returns across the network as well as the dependence of stock return on topological measures. Finally, whether the idea of "epidemic" or a"cascade" is a metaphor or model for this crisis will be discussed.

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I. INTRODUCTION

The barely covered story of rising foreclosures among the condominiums of Florida or California in early 2007 was a harbinger of a much larger collapse in the world-wide financial system. The increase of foreclosures over the priced in foreclosure risk in mortgage backed securities, otherwise deemed high-grade assets, began the confusion of the value of collateral assets and subsequent seizing up of credit markets around the globe. The collapse of several institutions such as Bear Stearns, Lehman, and Fortis has accentuated the level of crisis now facing the world markets. Previously loosely regulated titans of finance such as hedge funds and private equity groups have been hit by waves of unprecedented losses and demands by investors for redemptions, causing them to sell even more assets or close positions and creating a positive feedback death spiral.

Though the hardest hit markets are lesser-known markets such as commercial paper, the equity markets have become the most widely known indicators of the ongoing meltdown. In fact, most non-experts likely use the movements of the equity markets, fallaciously, as a key gauge of the severity or progress of the crisis. The equity markets, however, did not originate the crisis nor are they the key force perpetuating it. In this short paper, the spread of the credit crisis will be discussed by referring to a correlation network of stocks in the S&P 500 and NASDAQ-100 indices. The fact that the spread resembles a contagion or cascade, however, may be mainly superficial given the underlying dynamics are completely different.

II. NETWORK CONSTRUCTION

In this paper, a stock correlation network is created similar to the one in work by [1, 2, 3, 4, 5]. A correlation matrix of the returns between the two stocks is created where the correlation between stocks i and j, ρ_{ij} is defined as

$$\rho_{ij} = \frac{E((X_i - \mu_i)(X_j - \mu_j))}{\sigma_i \sigma_j} \tag{1}$$

where X_i and X_j are the log-returns of stocks i and j at a given time, μ_i and μ_j are the mean value of the stock log-returns over the measured time period, and σ_i andσ_j are the standard deviations of i and j over the measured time period.

The correlation is taken over the time period August 1, 2007 to October 10, 2008 where each daily value of X is the log-return of the closing price from the previous day. As [1, 2] demonstrate, however, correlation is not a distance metric, therefore we create an adjacency matrix with weights on the edges matching the distance metric between stocks, i and j, defined as

$$d = \sqrt{2(1 - \rho_{ij})} \tag{2}$$

Using these distances we finally create a minimal spanning tree using the python-graph module and animate using pydot and Graphviz. Because over 500 stocks are included, the ticker labels are relatively small but the central part of the component is dominated (though not exclusively) by finance and service sector stocks which are heavily cross-correlated and thus tightly linked with each other, while the outer branches are more industry specific including utilities and basic materials and are the later impacted stocks by the credit crisis (see Figure 1).

The stocks in Figure 3, represented as nodes, are colored according to the following methodology based on the stock return since August 1, 2007.

Events in the figures are taken from the timeline at [6].

The fall in stock valuations flows outward in the correlation network from stocks with relatively high centrality in the center to those on the periphery which are more industry specific or otherwise uncorrelated to the core sectors of the stock market. In Figure 2 this spread is emphasized by showing the average return among stocks

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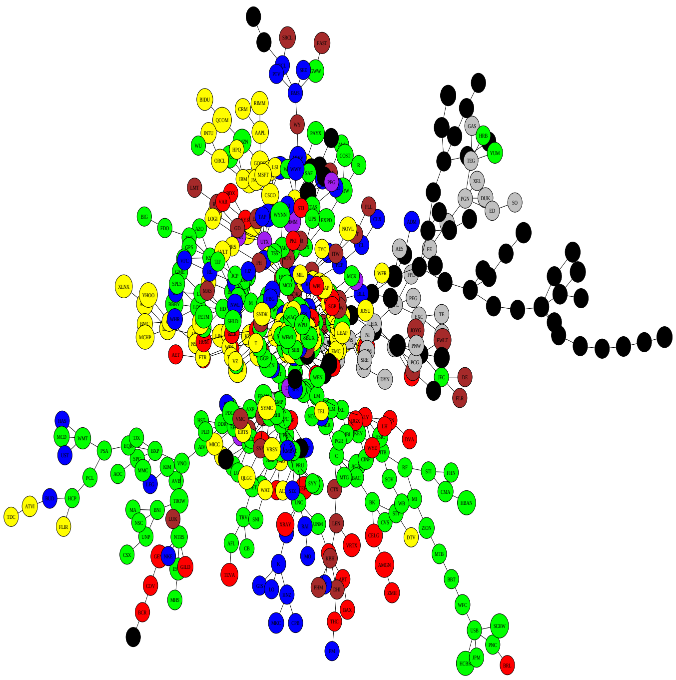


FIG. 1: Sectors represented by stocks in the network. Green are finance or service firms, red are healthcare, grey are utilities, yellow are technology firms, black are basic materials, purple are conglomerates, blue are consumer goods, and brown and industrial goods. Industry sector break outs are according to Hoovers.

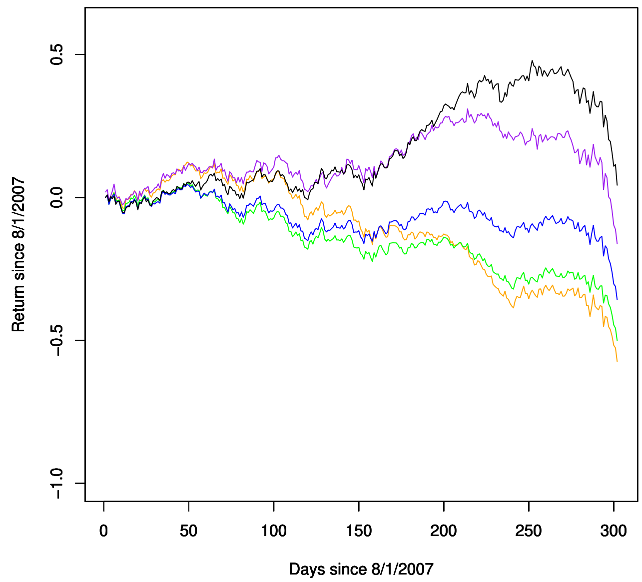


FIG. 2: Average returns of stocks from August 1, 2007 by distance from stock with the highest betweenness centrality (CBS). Orange is the average return of stocks at distance $0 < d \leq 0.4$, green at distance $0.4 < d \leq 0.8$, blue at distance $0.8 < d \leq 1.2$, purple at distance $1.2 < d \leq 1.6$, and black at distance $1.6 < d \leq 2.0$ (the maximum allowed by the metric in equation 2)

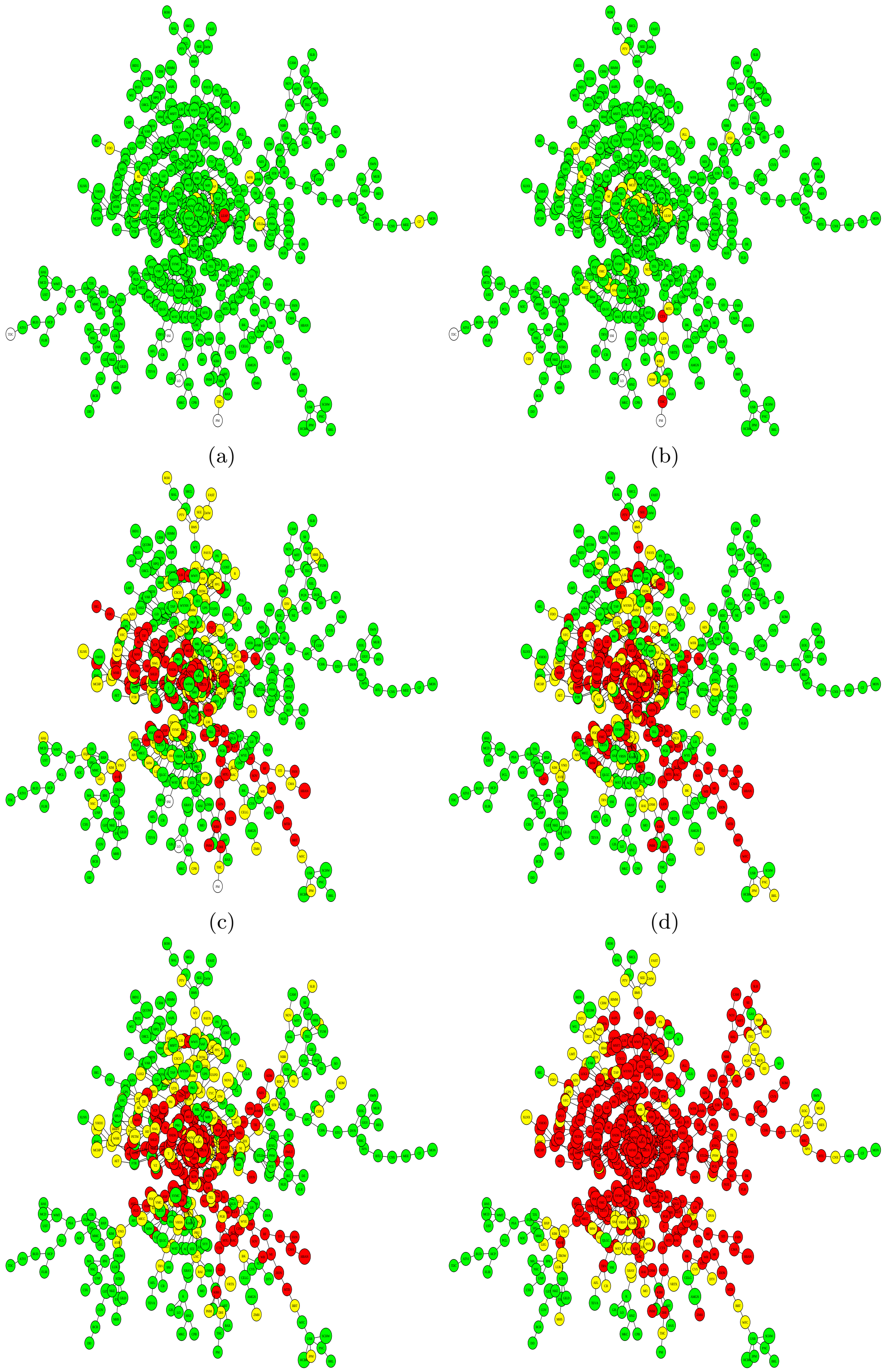
at a distance d from the stock with the highest betweeenness centrality (here CBS, a major S&P 500 stock and here classified under the services industry) where d is defined from equation 2. Here we see that the greater the distance from the central parts of the network, the more delayed the decline in valuation. Therefore the credit crisis spreads among affected stocks from more centralized nodes to more outer ones as the news of the extent of the damage to the global economy spreads.

III. DISCUSSION & CONCLUSION

Using methods of statistical physics and complex networks to investigate phenomena in stock markets is increasingly common [7, 8, 9, 10]. The increasing complexity and globalization of financial markets has led to many large and sometimes unpredictable effects. In [11] the effects of globalization upon the Korea Stock Exchange was demonstrated by showing the increasing grouping coefficient of stocks from 1980-2003. The credit crisis, however, presents a challenge of a whole new magnitude.

As has been viewed by the wider market, the collapse in stock price returns begins in the financial and services sector of the economy. Soon it moved across more mainline banks and firms and finally, more recently has affected stocks across the board. Though the spread of the collapse in stocks down the tree resembles an infection or cascade on a network, such ideas are more appropriately viewed as analogies or metaphors than explanations. Unlike a disease or cascading collapse, the stock crash is not being transmitted from one stock to another. What the collapse reveals is a complex and collective systemic collapse of the financial system which spreads as its extent becomes more recognized and affects the credit or demand for sectors across the economy.

The spread is carried both by the news of the extent of the crisis expanding and the fact that similar asset bases and capital structures make highly correlated stocks similarly vulnerable. In addition as credit becomes restricted, capital flows formerly relied on as a given begin to disappear causing financial difficulties in companies and selling of equities (among other assets) to raise capital. As panic and the extent of the devastation spreads, stocks are punished accordingly. In normal times, the failure of a company and its stock is not a cause for a systemic crisis. Also, since the correlation was calculated over an entire year's activity, the stock prices are correlated since they tend to fall similarly over time. The correlation shown in this network does not cause the transmission chain of collapse but is inextricably tied to it. In addition, correlation generally increases with volatility (for example, see [12]) and negative returns effect volatility more than positive returns of the same magnitude [13, 14]. So over time the correlation has been increasing among stocks



(a) (b) (c) (d) (e) (f)

FIG. 3: Diagrams show the spread of the credit crisis across nodes of the stock correlation network for different dates. From the top left, (a)August 10, 2007 when the crisis in mortgage backed securities first began causing widespread market volatility, (b) September 14, 2007, the collapse of British lender Northern Rock and its bailout by the British government which accentuated the global spread of the crisis, (c) January 17, 2008, turbulence in January 2008 due to the increasing fear of instability in the financial sector, (d) March 17, 2008, the collapse of the once venerable Wall Street investment bank Bear Stearns, (e) September 15, 2008, the even more destabilizing collapse of Lehman Brothers, and (f) October 10, 2008 ending of the worst performing week for the Dow Jones Industrial Average in history. Green nodes represent a current arithmetic return greater than -10%. Yellow nodes represent a current return between -10% and -25%. Red nodes represent a current return less than -25%.

and the network will likely be more dense and structure differently due to the steadily increasing market volatility.

Finally, one should note, this is not an example of the widely cited 'financial contagion' in the press. Financial contagion refers to the coupling of financial panic across national borders and not among stocks in an exchange. However, these do illustrate the spread of the credit crisis and how what was once a problem among home builders and mortgage finance companies has engulfed the entire economy.

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