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

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Abstract

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 and by the dependence of the stock return on topological measures.

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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 worldwide 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 the 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, similar to the one in Refs. [1–5], is created. We start by defining a correlation matrix of returns between two stocks, where the correlation between stocks i and j, ρ_{ij} is defined as

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

with X_i and X_j being the log-returns of stocks i and j at a given time, μ_i and μ_j being the mean value of the stock log-returns over the measured time period, and σ_i andσ_j being 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

	Basic Materials	Conglomerates	Consumer Goods	Financial	Healthcare	Industrial Goods	Services	Technology	Utilities
Basic Materials (61)	0.65	0.68	0.46	0.52	0.46	0.62	0.52	0.58	0.6
Conglomerates (7)	0.68	0.88	0.62	0.69	0.60	0.79	0.7	0.74	0.75
Consumer Goods (61)	0.46	0.62	0.48	0.53	0.45	0.56	0.52	0.53	0.55
Financial (85)	0.52	0.69	0.53	0.64	0.49	0.63	0.59	0.59	0.6
Healthcare (49)	0.46	0.60	0.45	0.49	0.46	0.53	0.49	0.51	0.54
Industrial Goods (42)	0.62	0.79	0.56	0.63	0.53	0.71	0.63	0.66	0.66
Services (98)	0.52	0.7	0.52	0.59	0.49	0.63	0.59	0.60	0.61
Technology (100)	0.58	0.74	0.53	0.59	0.51	0.66	0.60	0.65	0.63
Utilities (30)	0.60	0.75	0.55	0.60	0.54	0.66	0.61	0.63	0.76

TABLE I: Correlations within and across stock categories from 8/1/1007 to 10/10/2008. The number in parentheses after the sector name in the rows is the number of companies in each category.

log-return of the closing price from the previous day. As Refs. [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. That matrix is defined as

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

Using these distances we finally create a graphical minimal spanning tree by using the python-graph module, 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 certain 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, basic materials, technology, and some less-central financial stocks. These are the stocks later impacted by the credit crisis (see Fig. 1). The average correlations among stocks both within each category and between stocks of each category are given in Table I.

The stocks in Fig. 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 Ref. [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 Fig. 2, this spread is emphasized by showing the average return among stocks at a distance

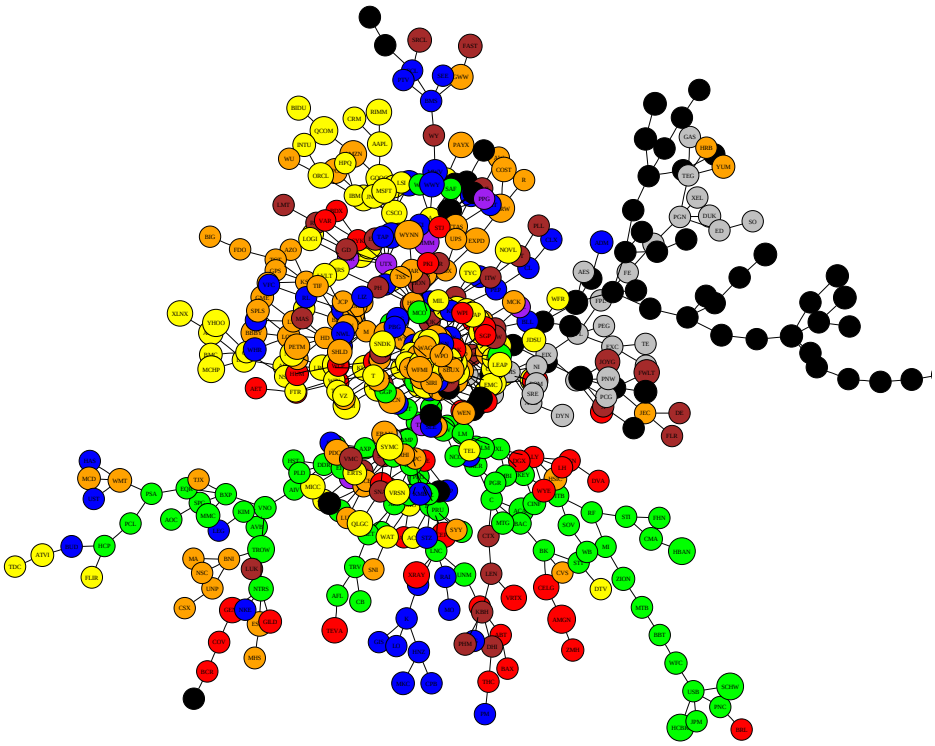

FIG. 1: Sectors represented by stocks in the network. Green is for finance firms, orange is for service firms, red for healthcare, grey for utilities, yellow for technology firms, black for basic materials, purple for conglomerates, blue for consumer goods, and brown for industrial goods. Industry sector breakouts are according to Hoovers[15].

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 by Eq. 2. Here, we see that the greater the distance from the central part 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 [7–10]. The increasing complexity and globalization of financial markets has led to many large and sometimes unpredictable effects. In Ref. [11], the effects of globalization upon the Korea Stock Exchange were demonstrated by showing

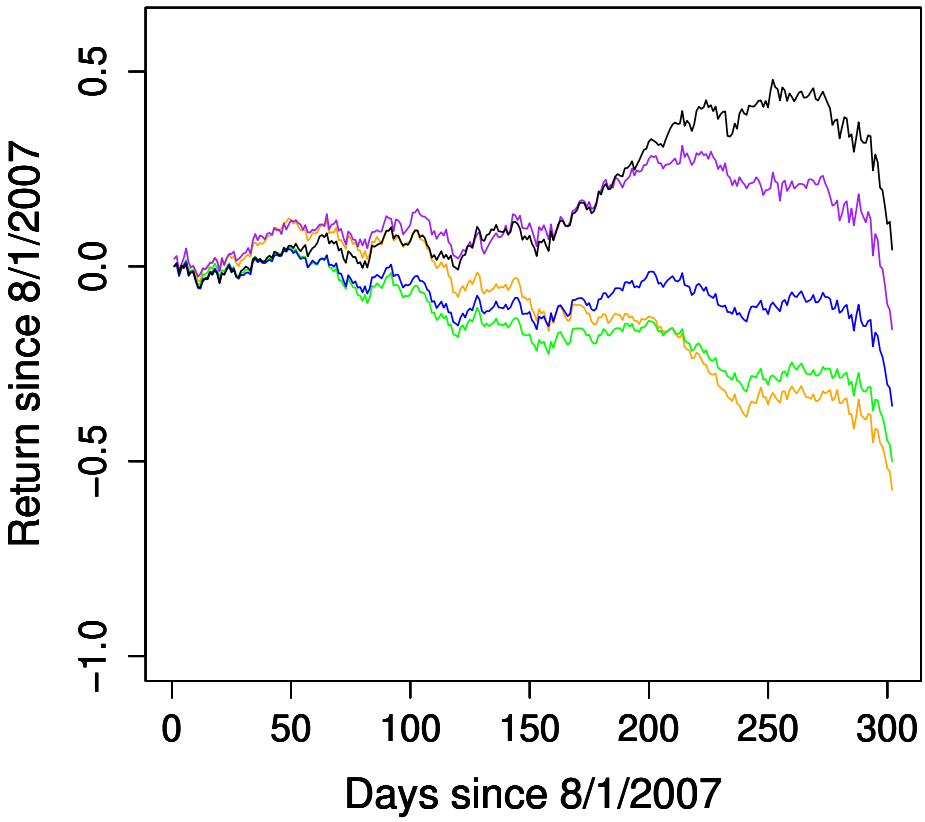

FIG. 2: Average returns of stocks from August 1, 2007 by distance from the stock with the highest betweenness centrality (CBS). Orange is the average return of stocks at distance $0 < d \leq 0.4$, green at distance $0.4 < d \leq 0.8$, blue at distance $0.8 < d \leq 1.2$, purple at distance $1.2 < d \leq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

the increasing grouping coefficient of stocks from 1980-2003. The credit crisis, however, presents a challenge of a whole new magnitude.

As viewed by the wider market, the collapse in stock price returns began in the financial and services sector of the economy. Soon it moved across more mainline banks and firms, and 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 and the fact that similar risky asset bases make the co-movement of certain stocks more likely and thus more highly correlated. 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 spread, 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 because 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, the correlation generally increases with volatility (for example, see Ref. [12]) and negative returns affect volatility more than positive returns of the same magnitude [13, 14], so over time, the correlation has been increasing among stocks, and the network will likely be more dense and structured differently due to the steadily increasing market volatility.

Finally, one should note that 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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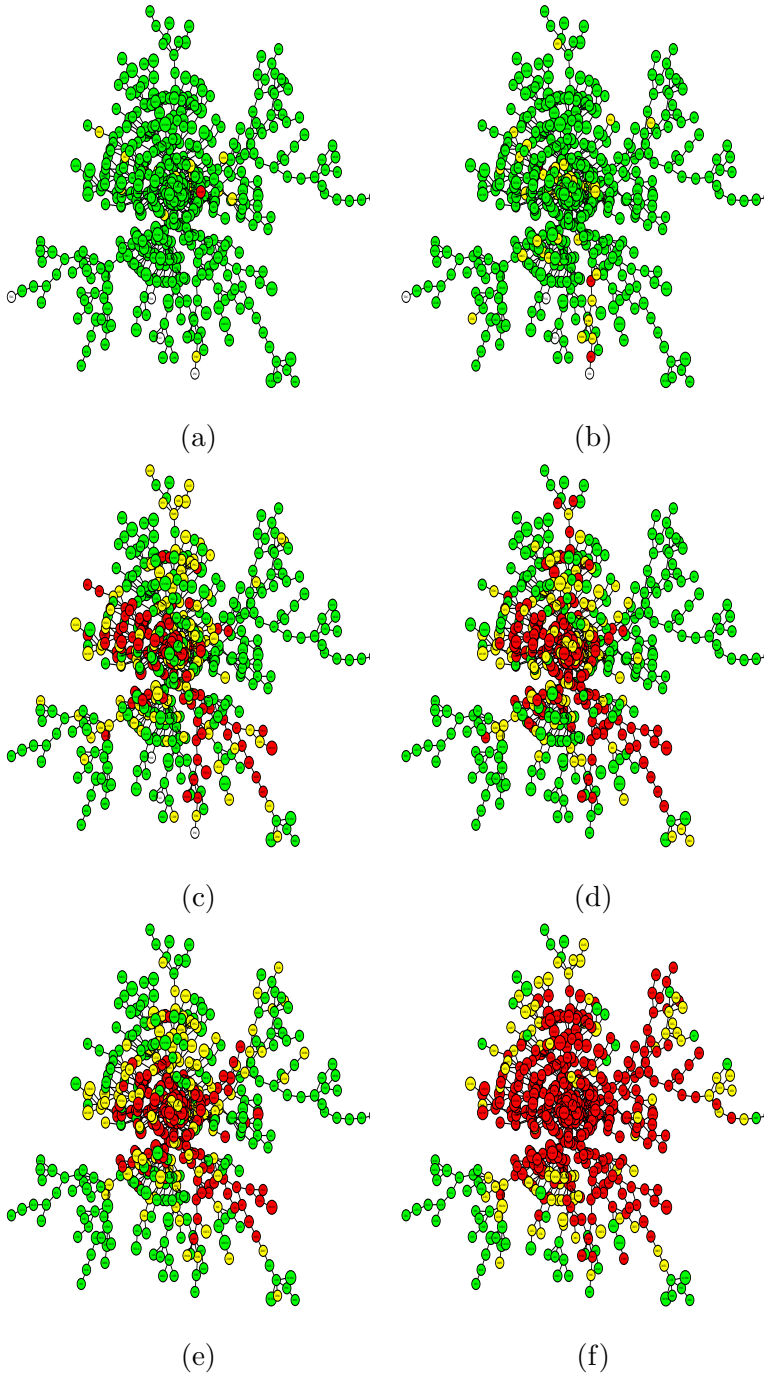

FIG. 3: Diagrams show the spread of the credit crisis across nodes of the stock correlation network for different dates. From the top left, (a)August 10, 2007, when the crisis in mortgage-backed securities first began to cause widespread market volatility, (b) September 14, 2007, the collapse of British 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, end 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%.