SUMMER 2013 VOL.54 NO.4

MITSloan
Management Review

INTELLIGENCE

Can High-Frequency Trading Drive the Stock Market Off a Cliff?

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REPRINT NUMBER 54404

[FINANCE]

Can High-Frequency Trading Drive the Stock Market Off a Cliff?

Much of the time, high-frequency trading firms play a benign role in financial markets. But in a nervous market with downward price pressure, high-frequency trading can create fierce volatility.

BY WEI PAN, ALEX SANDY PENTLAND, REN CHENG AND LISA EMSBO-MATTINGLY

On May 6, 2010, at around 2:40 p.m., U.S. stock market indices suffered a sudden drop of 9%, evaporating over one trillion dollars within 30 minutes. The event was known as the "flash crash," and it has been the subject of much discussion and analysis since that time. The U.S. Commodity Futures Trading Commission and the U.S. Securities and Exchange Commission investigated the cause of the flash crash and, in a September 2010 report, identified the initial catalyst as a single large sell order, with high-frequency trading then helping accelerate the market decline. That conclusion, in turn, triggered further discussion, as some believe that the report overstated the role of the single sell order.

However, there is no mystery behind the price declines that occurred during the flash crash: Price declines happen when there are more sellers than buyers in the market. Imagine a market composed of 10 sellers, all eager to sell the same product, and with only one buyer in the market. The only way sellers can compete for the sole buyer is to reduce the price. The heated competition for buyers created by the flash crash of 2010 temporarily took the stocks of some companies, such as Accenture PLC, to just a penny. The real question is: What caused this sudden and violent imbalance between buy and sell pressures during the flash crash?

Because the crash happened at a speed beyond any human's reaction time, many people suspect that the high-frequency trading industry was responsible for it. High-frequency trading firms use fully automated computer systems to buy and sell stocks very rapidly — and make thin profits by being ahead of human orders. After conducting a computer simulation of high-frequency trading behavior, we have gained new insights into the role of high-frequency trading in events like the flash crash. This is our version of the story.

The Crowd and the Bridge

Our story begins with an analogy — to the Millennium Bridge in London. When the Millennium Bridge first opened in June 2000, as many as 2,000 people at a time began to walk across the bridge. Shortly after, they started to feel the bridge vibrate and sway, with no apparent cause such as wind or an earthquake. The bridge movement was so visually frightening that a video of the event became popular on YouTube. Authorities had to close, reengineer and then reopen the bridge, a process that took more than a year and a half. The cause, engineers later discovered, was the interaction between the pedestrians and the bridge.

The problem was that the bridge could not be stable if 2,000 people on the bridge were moving in synchrony at the bridge's vibration frequency. During the opening, when the bridge oscillated and shifted to one side slightly, many pedestrians in the crowd responded by instinctively shifting

Shortly after London's Millennium Bridge first opened in June 2000, a crowd of pedestrians started to feel the bridge vibrate and sway as they walked across it.

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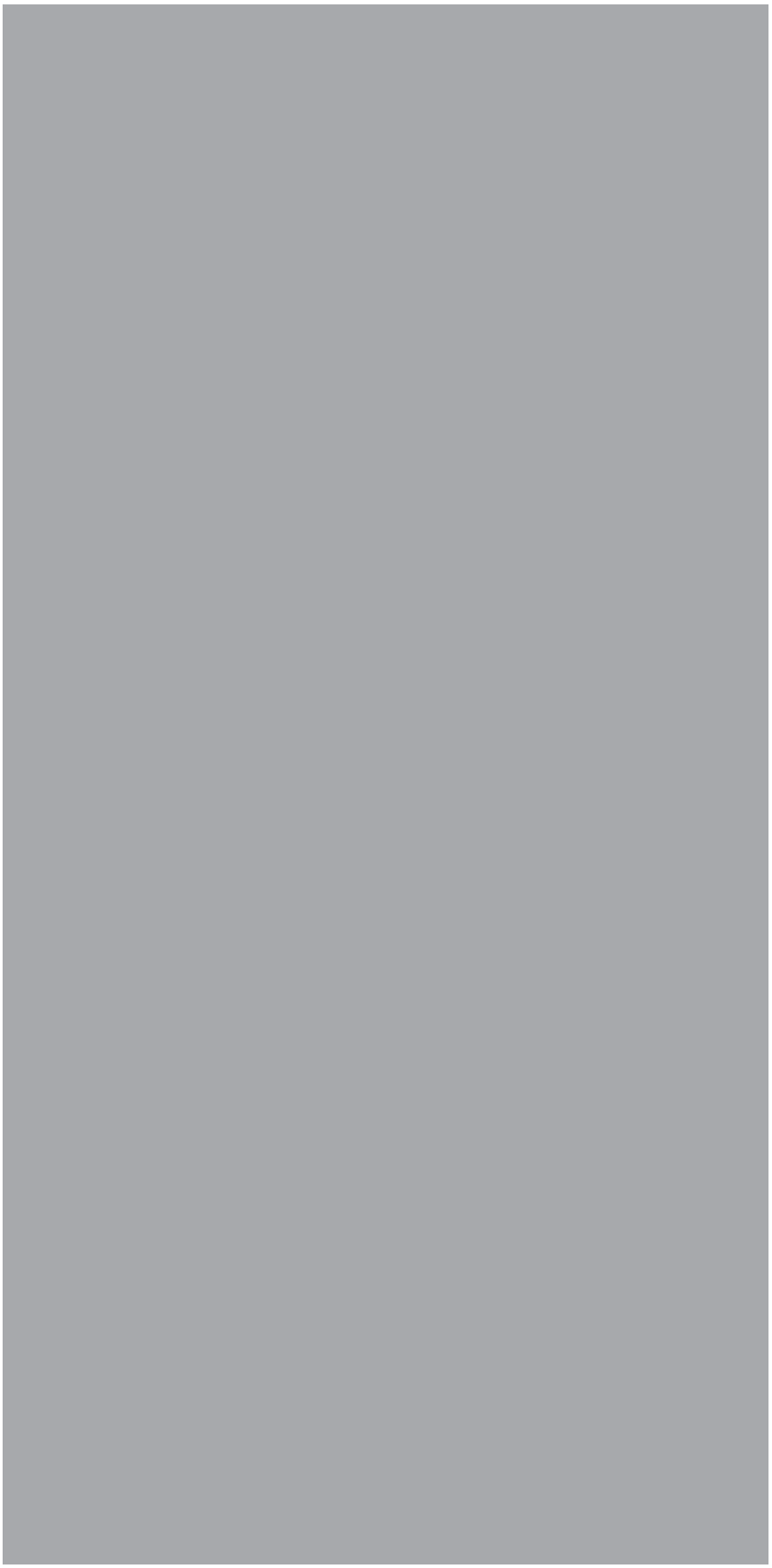
their weight to the other side of their bodies in order to balance themselves. The packed crowd also pushed against each other, which reinforced the synchronization of their movements. The power in their motion fed back to the bridge, causing even more swings — and, in response, even more synchronized human movements.

Synchronized Selling

Our simulation findings suggest that something analogous happened with high-frequency trading firms during the flash crash, in that the firms became synchronized toward the sell side in a way that increased market volatility. We know how high-frequency trading firms trade in general from an earlier analysis of the trading data from May 6, 2010, that was conducted by researchers who were at the time affiliated with the CFTC. (See "Further Reading.") Using data from that analysis, we could create strategies for 20 hypothetical high-frequency trading firms. (The SEC and the CFTC identified about 20 high-frequency trading accounts involved in the crash.) These strategies essentially involve buying and selling particular securities frequently at different time intervals, an approach known as mean reversion strategy. Each high-frequency trading firm trades approximately every 10 to 20 seconds, buying when the price goes down slightly and selling when the price goes up. High-frequency trading firms are secretive — they do not communicate with each other directly — and consequently act independently.

We then fed the strategy of each of our 20 hypothetical high-frequency trading firms into a computer and simulated their behaviors, a method known as agent-based modeling. Because the experiment was simulated, we could also compute things one cannot measure in the real world, such as the hypothetical prices in the market assuming high-frequency trading firms were not present.

(Continued on page 18)



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What happened when we ran the model assuming that real investors were trading randomly — with half buying and half selling? Good things. Under a simulation with such circumstances, high-frequency trading firms did not influence the market price much and in fact made the market smoother and less volatile. Some high-frequency trading firms were buying while others were selling due to the diversity of their strategies, and the market enjoyed the abundance of liquidity by experiencing smoother price changes.

But that scenario assumed a very calm market. We also simulated a market with more nervous market participants and, in addition to random behaviors of real investors, general strong downward pressure as people are trying to get out of the market. That is more likely to reflect the conditions of May 6, 2010. In the time period between late April 2010 and the flash crash, the NASDAQ index had dropped 10%, and some mutual funds were initiating large sell orders, creating downward price pressure.

When we ran a simulation with such downward price pressure, the hypothetical market that did not include high-frequency trading firms declined slowly. But the market price in the hypothetical market that included 20 high-frequency trading firms appeared to be very similar to an actual flash crash: It was stable for a while — and then, suddenly, a crash occurred. Without the high-frequency trading firms, the market would decline in a more manageable and gradual fashion.

In our simulation, each high-frequency trading firm had a limited budget, so that no single entity could crash the market — much as no individual alone could make the Millennium Bridge sway perceptibly. Much like the feedback loop between the pedestrians and the Millennium Bridge, high-frequency trades influenced the market price, which then affected the next trades of the high-frequency trading firms. As a result, many of these high-frequency trading firms started to sell together, in synchrony, which added up to billions of dollars worth of sell trades per second. This was an event of enormous magnitude, even for the U.S. equity market. The synchronized selling caused prices to collapse.

FURTHER READING

- **A.A. Kirilenko, A.S. Kyle, M. Samadi and T. Tuzun, "The Flash Crash: The Impact of High Frequency Trading on an Electronic Market" (2010 working paper, updated May 26, 2011). Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1686004.**
- **For more details about the authors' simulation, see W. Pan, A.S. Pentland, R. Cheng and L. Emsbo-Mattingly, "High Frequency Trading: A Simulation," (working paper, Dec. 20, 2012). Available at http://web.media.mit.edu/~panwei/pub/hft_smr.pdf.**

Our simulations suggest that the problems with high-frequency trading synchronization occur when there is a trigger — strong downward pressure on the market. (See "Further Reading" for more details about our simulation.) Without triggers, high-frequency trading firms remain benign — and even helpful — market participants. When we gradually added downturn pressure to price movements in a hypothetical market with 20 high-frequency trading firms and ran thousands of simulations, we found that the market remained stable until downward drift hit a certain threshold. We believe that the U.S. stock market passed this threshold on May 6, 2010.

Lessons Learned

The common factor between the crowd on the Millennium Bridge and the high-frequency trading firms in the stock market is that both represent complex systems in which many independent entities are strongly interacting with each other either directly or indirectly.

The lesson for those managing complex systems is to be extremely cautious about those systems' behavior: They will often react in ways that are surprising. Because complex systems are interconnected and contain feedback loops, their dynamics can evolve into extreme phases. Most of the time, a complex system will act in expected ways, but it may turn into an unfamiliar monster when an invisible tipping point is passed. Since the extreme phases of these systems may be rare, they are not well studied, and so are not always factored into decision making.

For financial market makers, the lesson is that synchronization of high-frequency trading firms (such as synchronized selling) must be monitored, and high-frequency trading orders should be automatically paused when synchronization levels hit a threshold, such as three standard deviations above normal activities. Similarly, systemic risk tests should be conducted according to the principles of complex systems — looking at how elements of a system are connected and how they act together under such connection. We also believe that humans, both at high-frequency trading firms and in regulatory agencies, should constantly monitor high-frequency trades. Intuition is still better than computer models in handling complex cases.

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