

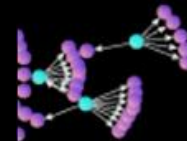


Saïd Business School
UNIVERSITY OF OXFORD



High-Frequency Trading: What is it Good for?

Austin Gerig
University of Oxford



fec
forecasting financial crises

Motivation

- High-speed computerized trading -- known as high frequency trading (HFT) -- dominates modern financial markets (~50% of trades).
- Evidence suggests HFT increases market efficiency.
- However, there are serious concerns that HFT is:
 - is unfair.
 - is destabilizing.
 - syphons money from markets with no added social benefit.

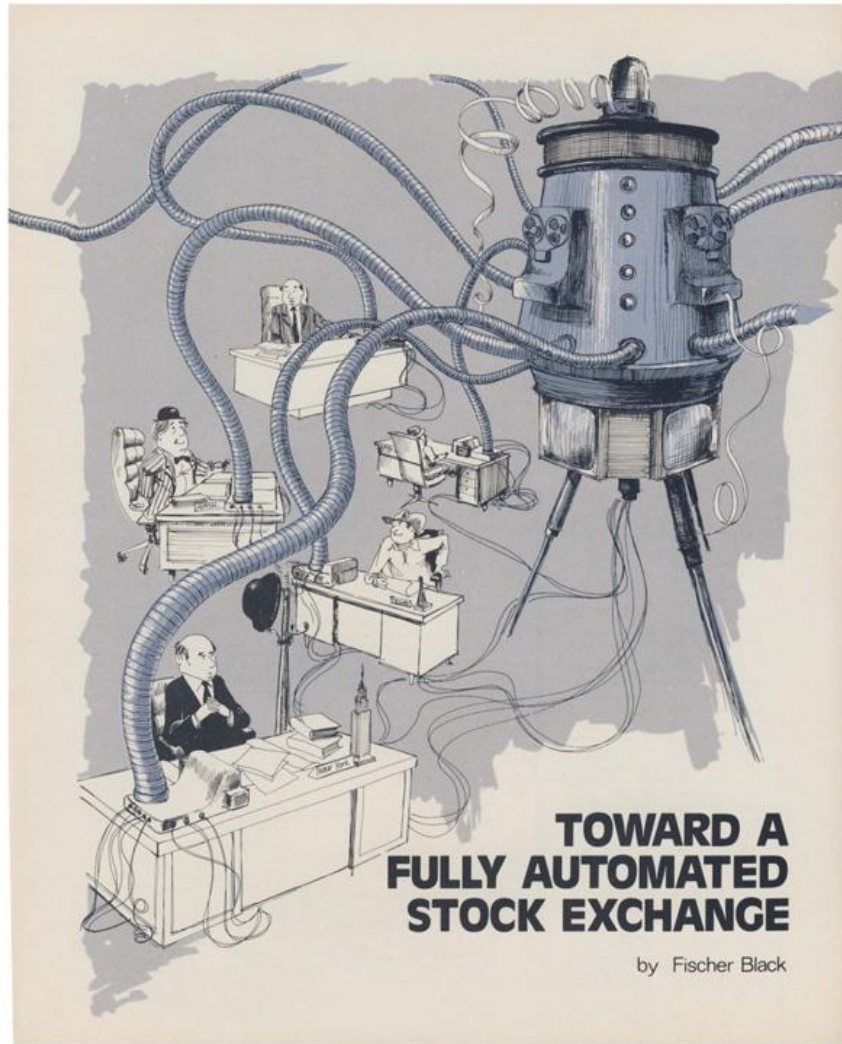
Results

- Using a special dataset from NASDAQ, I show that HFT synchronizes security prices.
- With a simple model (and drawing parallels with recent work in ecology), I demonstrate how synchronization:
 - increases the accuracy of prices.
 - lowers transaction costs.
 - increases instability during times of market stress.

What is high frequency trading (HFT)?

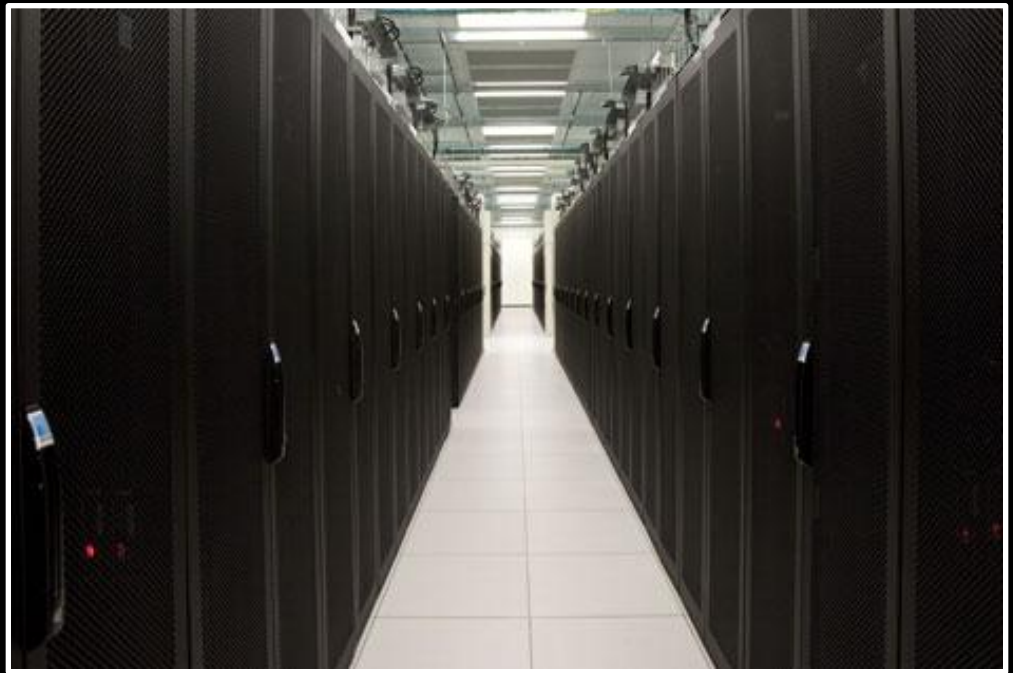
- HFT is autonomous computerized trading that seeks quick profits using high-speed connections to financial exchanges.
- HFT is part of a larger trend towards automation in financial markets.



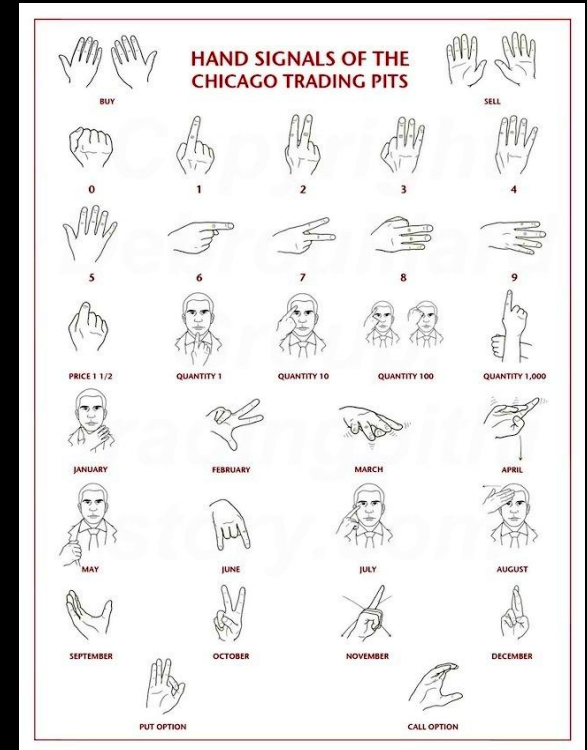


In 1971, Fischer Black predicted that most activity on financial exchanges could (and would) be automated.

NYSE today



Trading pit nostalgia

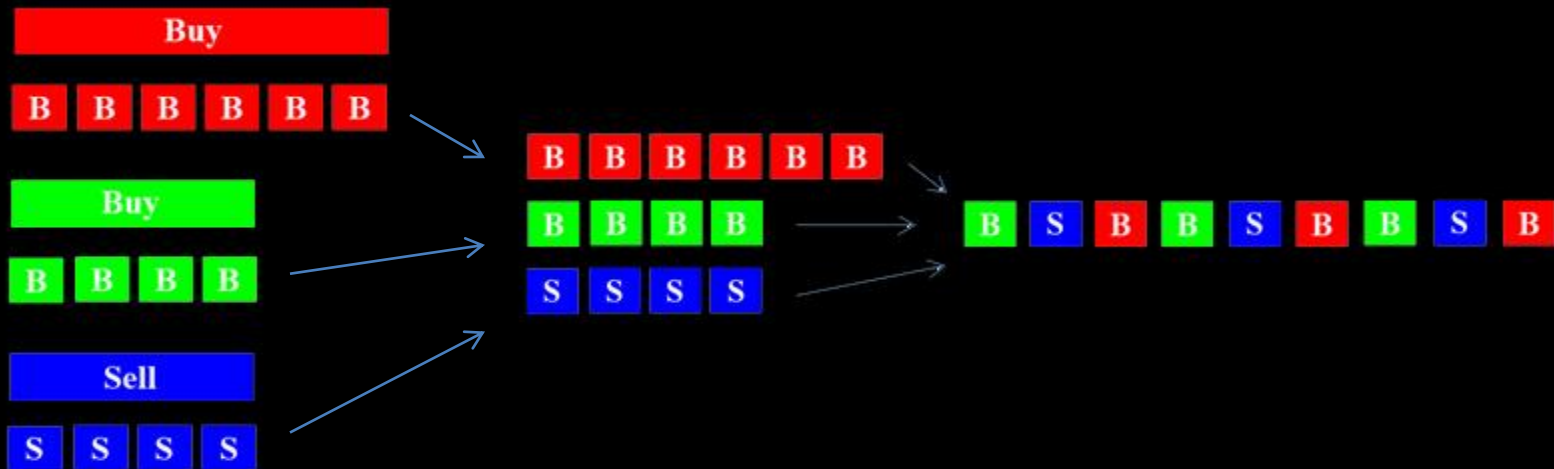


“Across Europe, Asia, Australia, South America and Canada it's already ceased as a form of communication with the closure of all derivatives trading pits in those regions. Only three futures exchanges in the US continue ... Eventually, these last remaining pits will close and end the functional purpose of the hand gestures that hundreds of thousands used to transact and share information since the late 19th century.”

<http://tradingpithistory.com>

Two categories of automation

- Algorithmic trading
 - Minimize the execution cost of a large long-term position.
 - On the floor this was known as “working an order” (see Gerig, Farmer, and Lillo (2011)).



- Note: Sometimes the term “algorithmic trading” is used to refer to any type of automated trading.

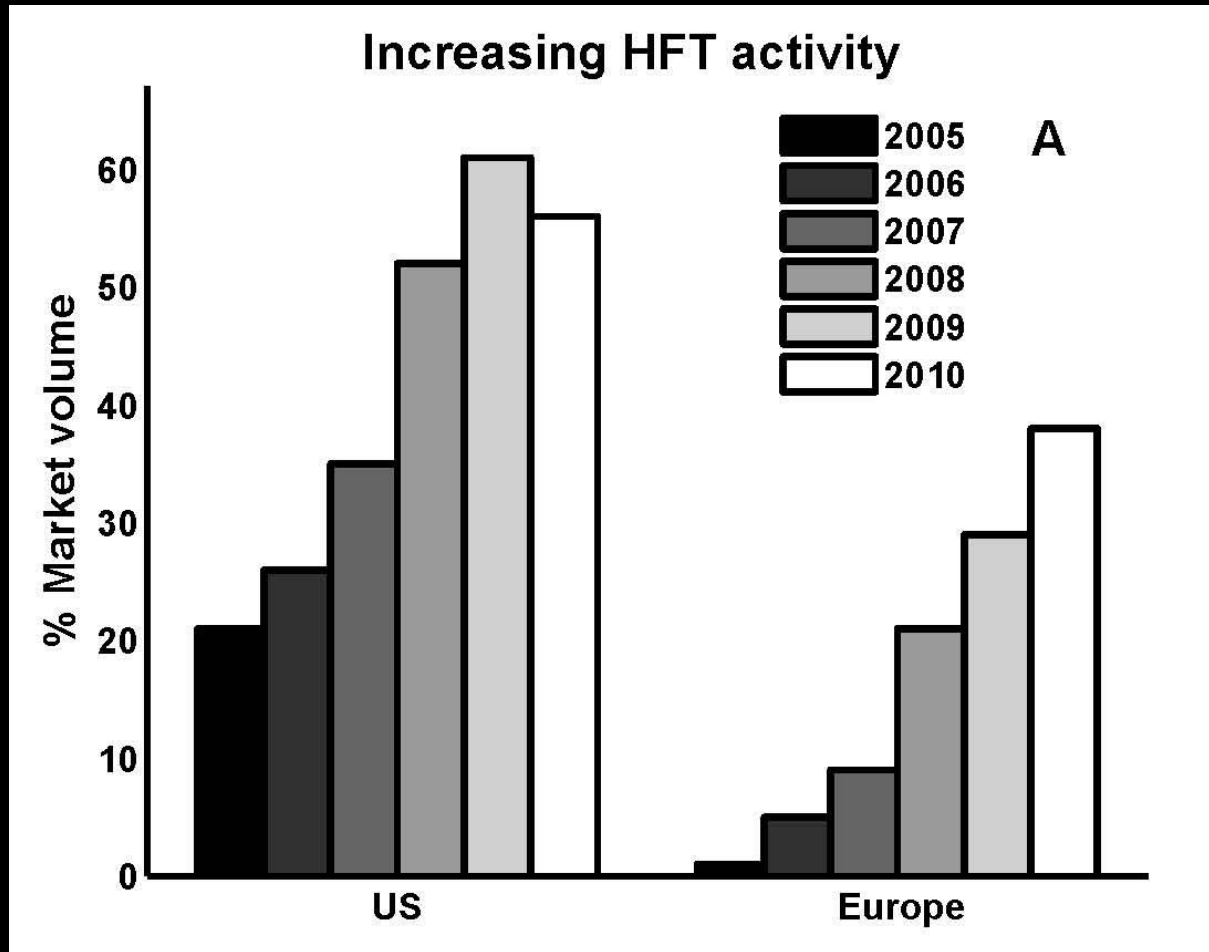
Two categories of automation

- High frequency trading
 - Short-term speculative trading.
 - On the floor this was known as “scalping” or “market making”

In some ways, HFT is small ...

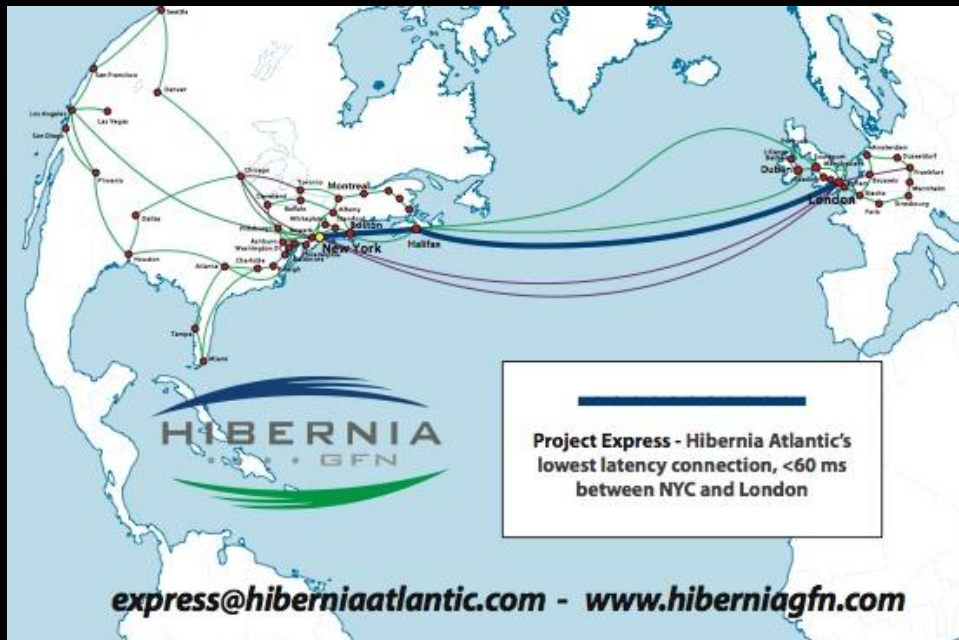
- Implemented by small, obscure proprietary firms.
 - Allston Trading, DRW Holdings, Getco, RGM Advisors, Tradebot, Tradeworx, etc.
 - Most firms have several hundred million USD in capital.
 - Large hedge funds typically have \$30 billion.
- Total revenues are relatively small .
 - Approx \$5 billion per year (Tabb Group).
 - Approx \$2.8 billion per year in US equities (Brogaard, 2010).
 - Total hedge fund revenue is ~100 times this.

... in other ways, HFT is large



US equity volume is measured in shares; European equity volume is measured in value. Source: TABB Group

... and influential



Time Is Money

The milliseconds saved by faster microwave networks could mean big profits for traders.

TYPE OF CONNECTION



FIBER OPTIC

Lines buried in the earth carry signals in pulses of light

PATH



Routes must avoid buildings and follow the terrain, adding distance

NJ TO CHICAGO TRANSIT TIME

6.55
MILLISECONDS



MICROWAVE

Signals are beamed between towers within sight of one another



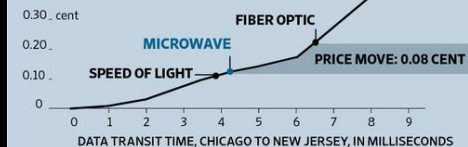
Signals follow a straight line, reducing transmission time

4.25*
MILLISECONDS

Microwave dishes in Carteret, N.J. →

The Value of a Millisecond

How quickly an ETF based on the S&P 500 in New York follows the change in price of an S&P 500 futures contract in Chicago.



The faster speed of a microwave network could mean a gain of 0.08 cent per share traded, one trading firm says.

*Speed claimed by Tradeworx network, under construction
Source: Tradeworx Inc.; Photo: Anton Troianovski/The Wall Street Journal

HFT is driving faster data connections between major financial centers.

HFT worries regulators

- A large portion of trading is “unrelated to the fundamentals of the company that’s being traded. It’s got very little to do with whether you think IBM’s got a great business plan . . . and a lot more to do with what’s the minuscule aberrational price move that you can take advantage of because you’ve co-located your computer with the exchange and can jump on that in microseconds. And that worries me in some ways.”
- Mary Schapiro, Chairman SEC



- “It is therefore not clear that high frequency trading, based on computer algorithms, can possibly deliver significant positive social value – price discovery at the nano-second interval cannot possibly give a significant allocative efficiency benefit over price discovery on a second-by-second basis.”

- Adair Turner, FSA Chairman



Numerous calls to study HFT ...

- SEC (United States)
 - “Concept Release on Equity Market Structure”
- BIS Foresight project (United Kingdom)
 - “The Future of Computer Trading in Financial Markets”
- ESMA (Europe)
 - “Guidelines on systems and controls in a highly automated trading environment for trading platforms, investment firms and competent authorities”
- European Commission
 - “Consultation on financial sector taxation”

... countless newspaper articles

THE WALL STREET JOURNAL

WSJ.com

MARKETS | Updated March 23, 2012, 12:34 p.m. ET

SEC Probes Rapid Trading

BY SCOTT PATTERSON AND JEAN EAGLESHAM

Federal securities regulators are examining whether some sophisticated, rapid-fire trading firms have used their close links to computerized stock exchanges to gain an unfair advantage over other investors, people familiar with the matter say.

The wide-ranging probe, being handled by the enforcement staff of the Securities and Exchange Commission, is focusing on the computer-driven trading platforms of exchanges, including BATS Global Markets Inc., the people said.

The SEC probe illustrates a bigger push by regulators to examine less-transparent parts of the securities markets, such as the fast-growing area of so-called high-frequency trading. High-speed trading firms use powerful computer systems for ...

The Economist

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High-frequency trading

The fast and the furious

High-frequency trading seems scary, but what does the evidence show?

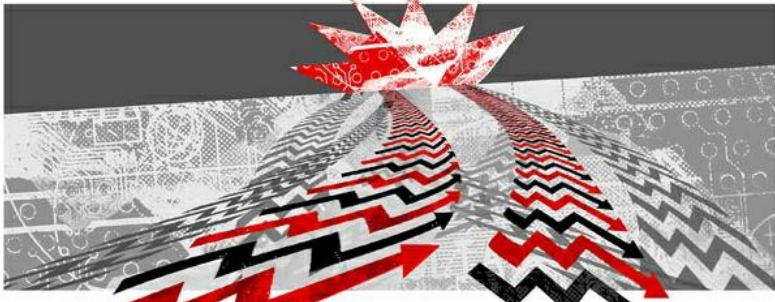
Feb 25th 2012 | from the print edition

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NEWS

US regulator convenes panel on HFT

The CFTC named the participants in a key panel set to discuss a definition and regulation of high-frequency trading later this week - Mar 26 2012

European MP calls for holding period in HFT

Computerised orders should be subject to a "minimum holding period" in stocks to slow down ultra-fast dealing, a top European parliamentarian says - Mar 23 2012

Commodity market's algorithmic challenge

UN paper finds 'striking' impact of high-frequency trading over very short periods, writes Javier Blas - Mar 26 2012

US bourses to fine HFT data-cloggers

Nasdaq and Direct Edge are to impose penalties on high-frequency traders who clog the markets' data pipes with unnecessary messages that do not result in trades - Mar 7 2012

Password

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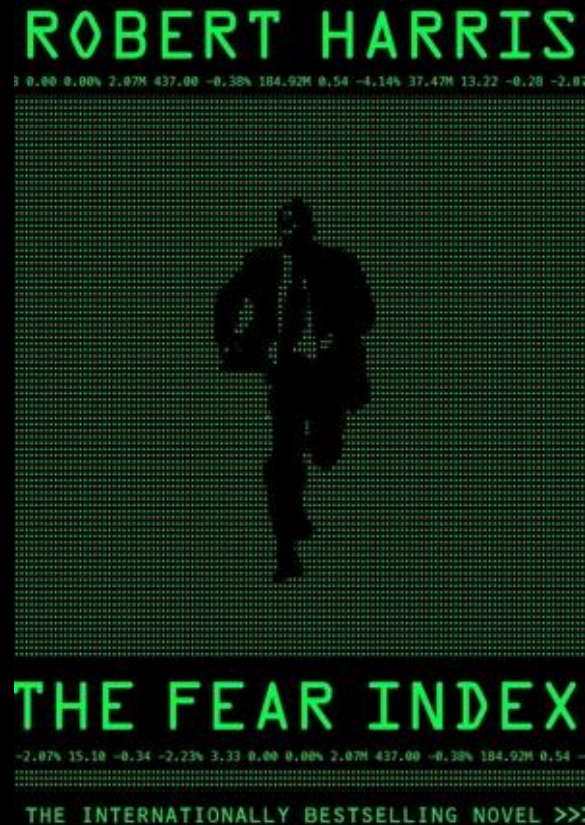
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ABOUT THIS PAGE

Looking for all the FT's coverage of high-frequency trading?

It's all here, gathered into one easy to view page. We have split the page into three sections: news coverage, analysis and comment, including Lex and the 'Quick View' column written by Jeremy Grant, editor of FT Trading Room.

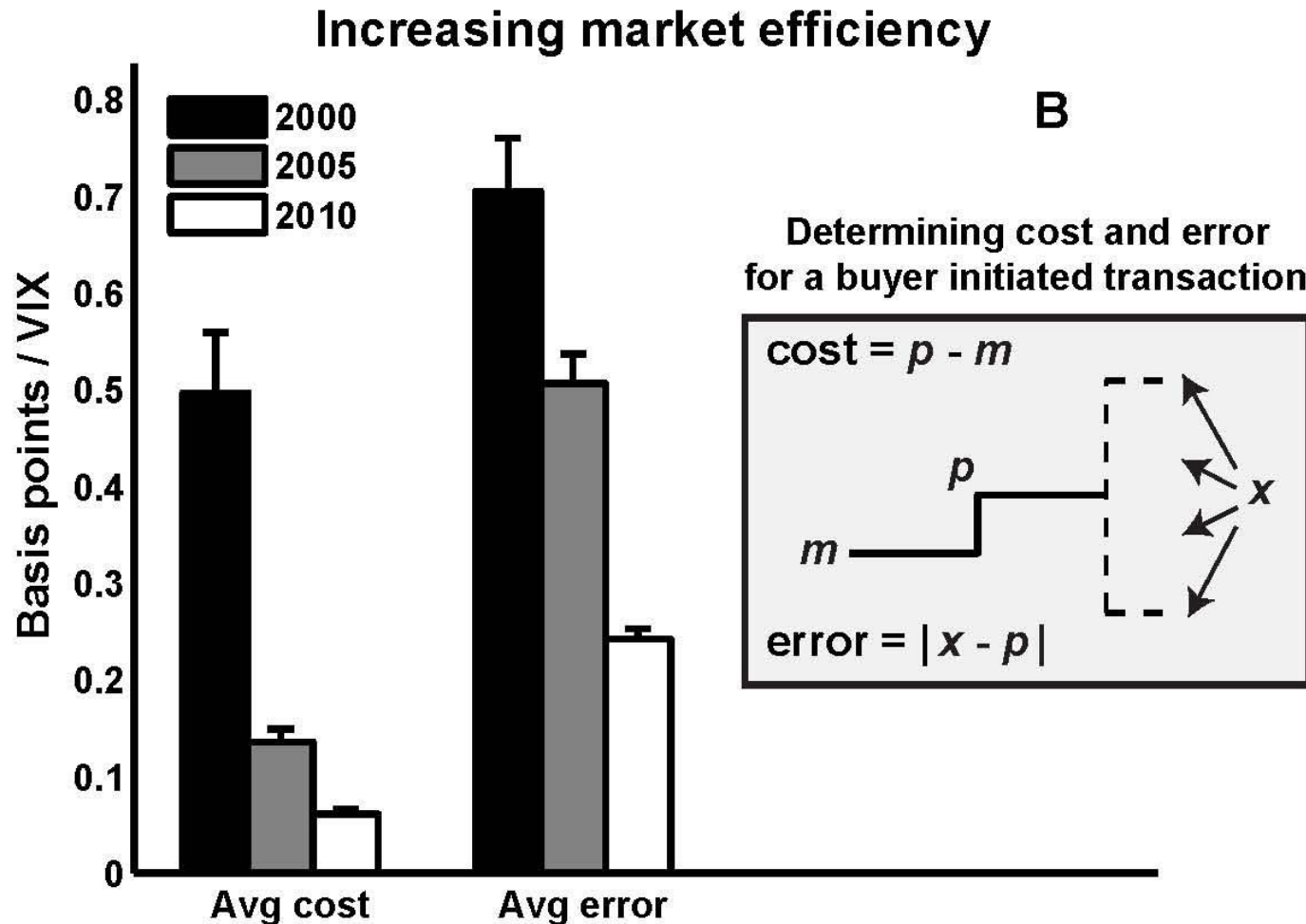
... even a novel



“At the nexus of high finance and sophisticated computer programming, a terrifying future may be unfolding even now.”

What do we know?

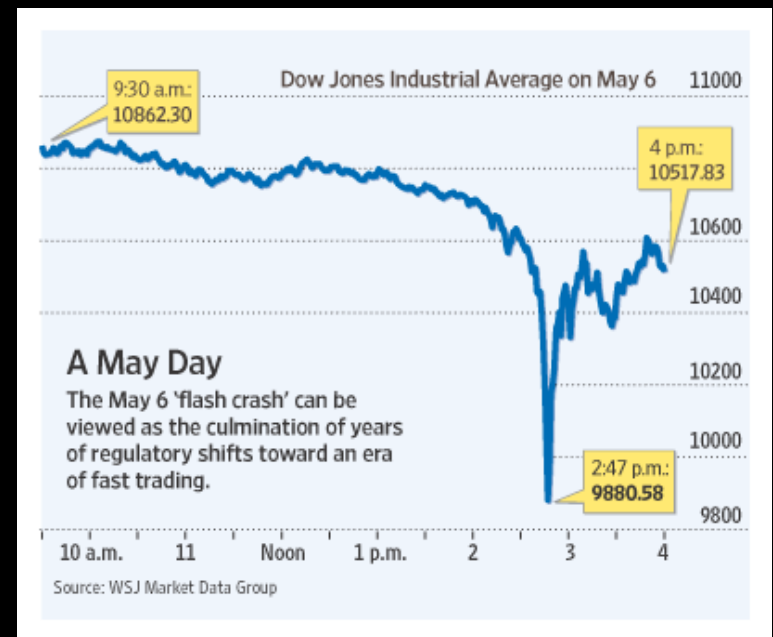
- HFT increases market efficiency:
 - Lowers transaction costs.
 - Increases the accuracy of prices.
- Sources:
 - (Hendershott et al., 2011)
 - (Hendershott and Riordan, 2011a)
 - (Hendershott and Riordan, 2011b)
 - (Brogaard, 2010)
 - (Castura et al., 2010)
 - (Menkveld, 2012)



Data from 35 large-cap US stocks during the last full week of February in 2000, 2005, and 2010. Error bars report the standard error of the mean across the 35 stocks (Gerig, 2012).

What do we know?

- HFT potentially:
 - Increases the instability of the market.
 - Creates spurious relationships in markets.
- Sources:
 - The rapid fall and subsequent rise in prices that occurred in US markets on May 6, 2010, was, in part, due to HFT. (Kirilenko et al., 2011)
 - Correlations between equities and commodities have steadily increased as HFT has increased. (Bicchetti and Maystr, 2012)



Yet we still know relatively little!!!

- We still don't know HFT's purpose.
- Is HFT needed?
- Where do profits come from?
- Does society benefit from microsecond speeds?
- Should we tax HFT?

The great mystery

- “Apparently, it (HFT) leads to market efficiency and better price determination, but if people are making profits out of it, where are the profits coming? It seems to me ultimately that they are coming from my members and I do worry about that.”
- Chris Hitchen, Chief Executive of the Railways Pension Trustee Company

A PROPOSAL:

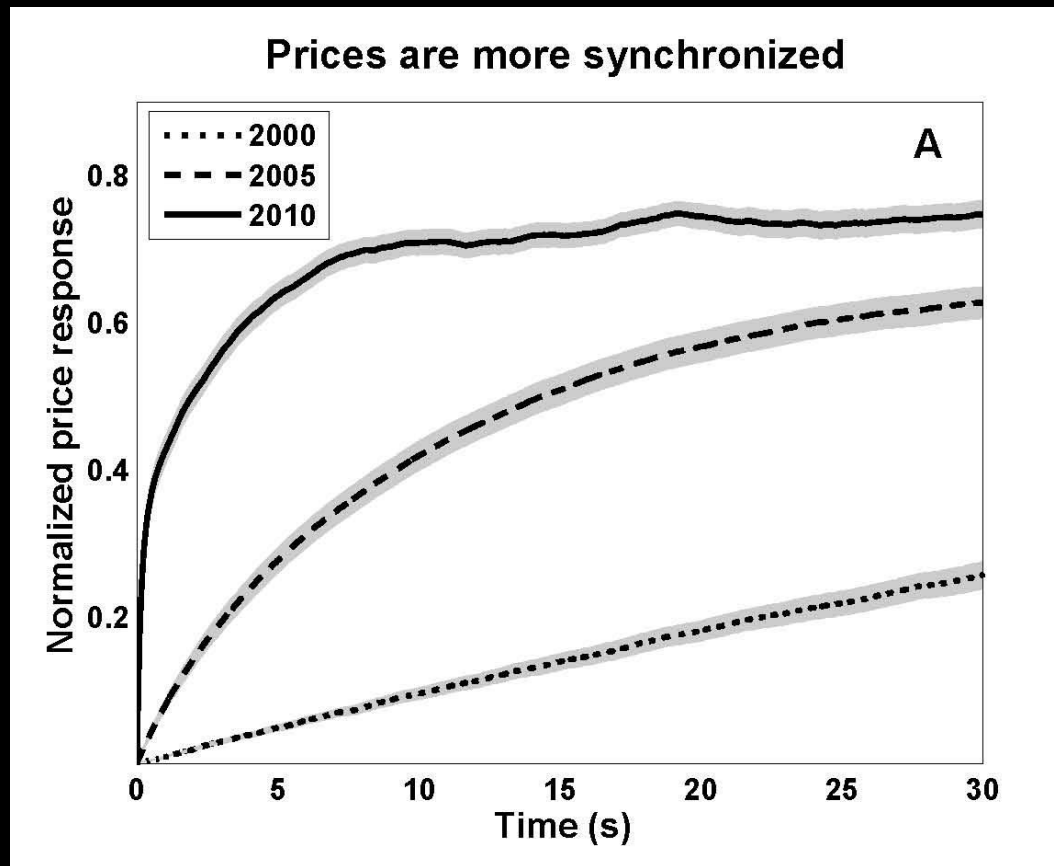
- HFT synchronizes security prices
 - To the extent that two securities are related to one another, HFT activity ensures that a price change in the first security coincides nearly instantaneously with a similar price change in the second security.
- Synchronization:
 - increases the efficiency of markets.
 - can be profitable for the firms that do it.
 - is impossible to do without high-speed computerized trade.

THE EVIDENCE

NASDAQ data

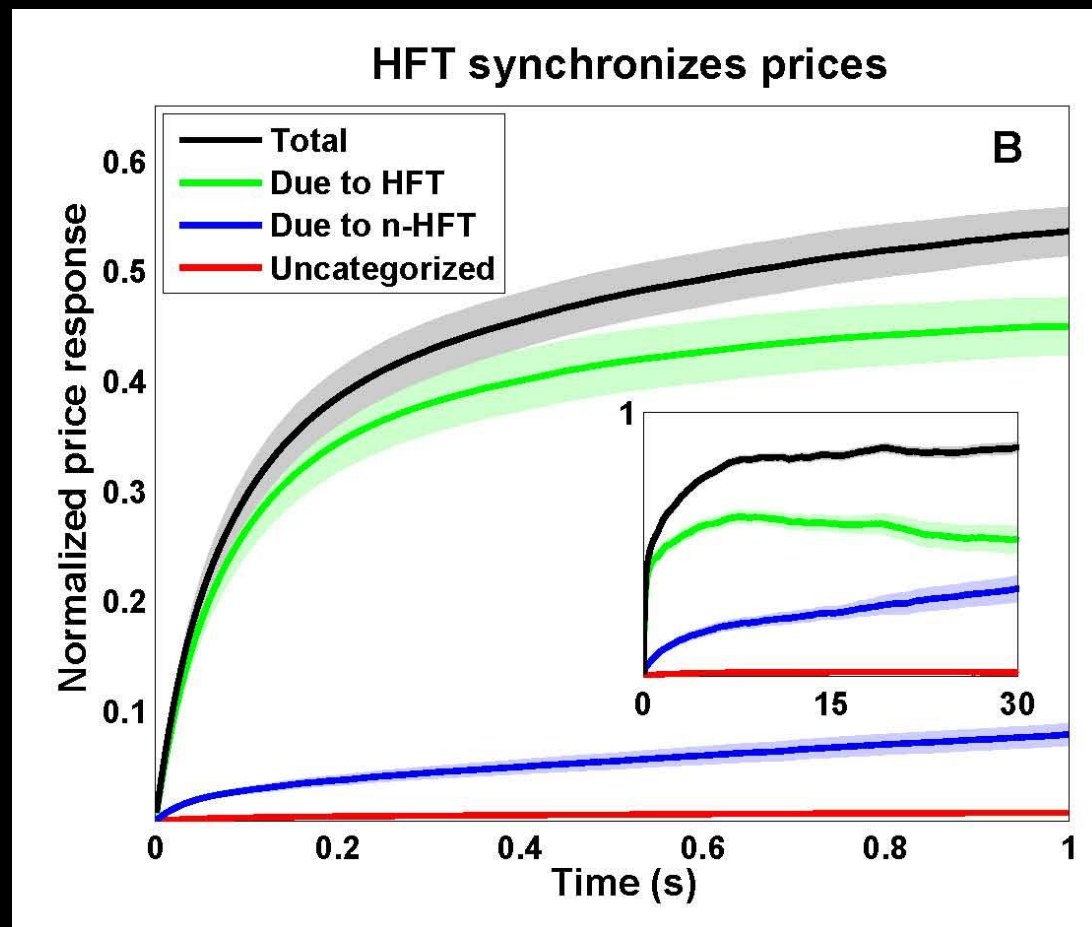
- Market data for 120 stocks (40 of which are large-cap stocks) traded on NASDAQ from Feb. 22-26, 2010.
- All market activity from 26 proprietary HFT firms is flagged. I know all of their trades and quotes.
- I supplement this data with Thomson-Reuters tick data for 35 of the 40 large-cap stocks (data is from the same period in 2000, 2005, and 2010).

Prices are more synchronized ...



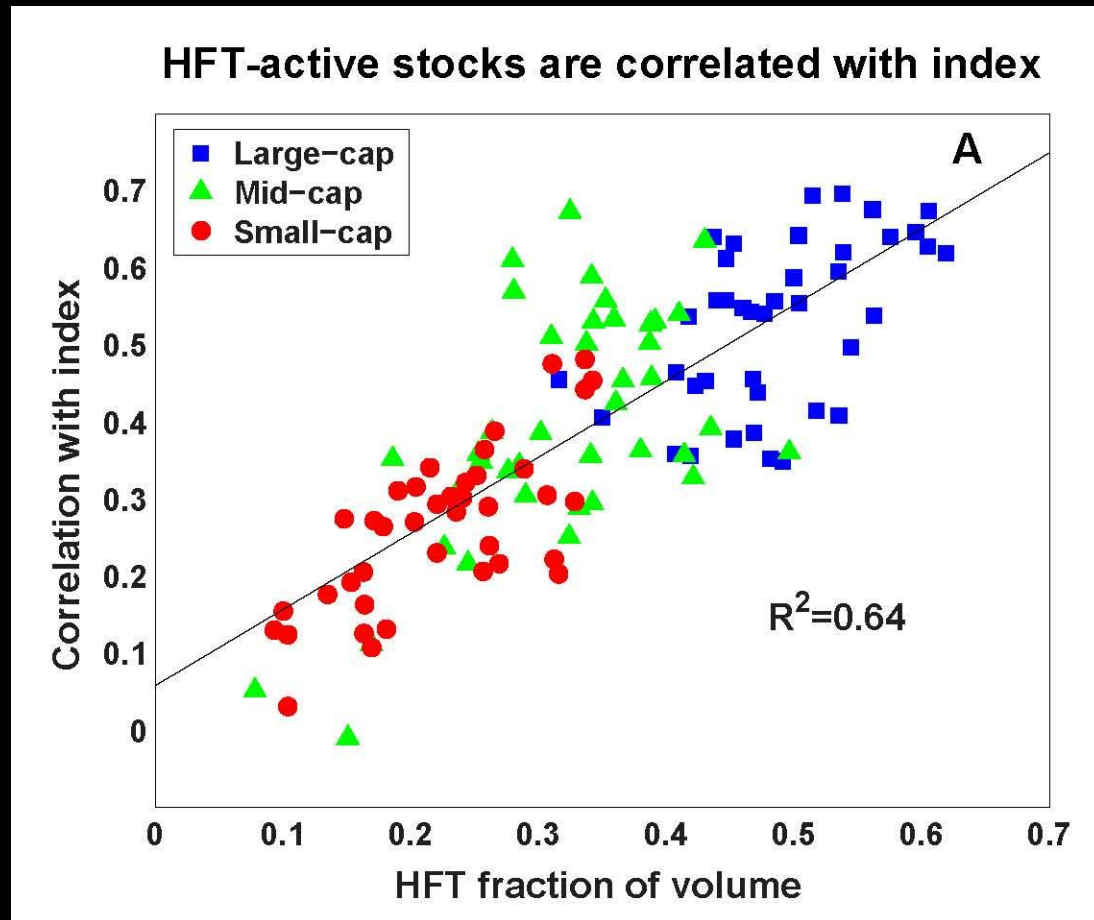
Normalized price response of stock i to a price movement of stock $j \neq i$. Data is from 35 US large-cap stocks during the last full week of February in 2000, 2005, and 2010. The standard error of the mean across the 35 stocks is shown in gray (Gerig, 2012).

... this is due to HFT



The price response of the full 40 US stocks in Feb. 2010 (black) is decomposed into the amount due to HFT activity (green), non-HFT activity (blue), and an amount that could not be categorized (red). Standard errors are shown in shaded color (Gerig, 2012).

Synchronization and HFT go hand-in-hand



Plot of stock correlation vs. the fraction of volume due to HFT for that stock. Correlations are between the 30 second returns of the stock and the equal-weighted average 30 second returns of all 120 stocks. Volume is measured in shares. (Gerig, 2012).

**WHAT ARE THE EFFECTS OF
SYNCHRONIZATION?**

Synchronization in nature

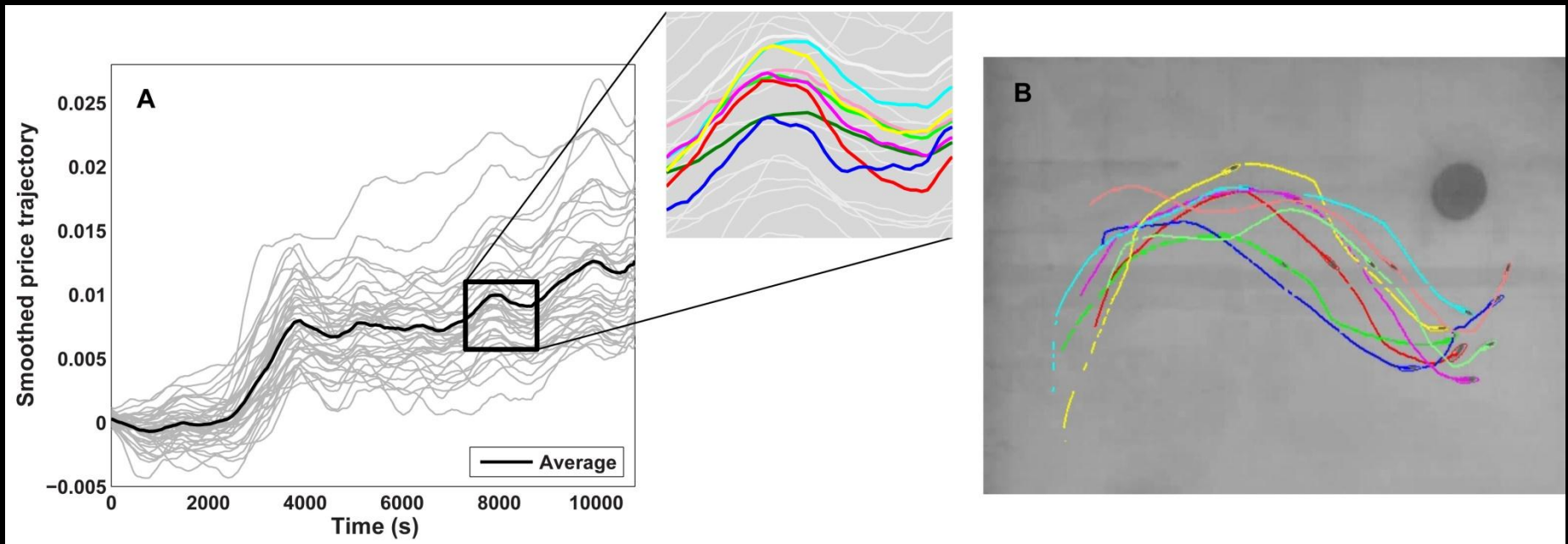


Animals that move synchronously propagate information quickly, even when only a small number of individuals are informed.

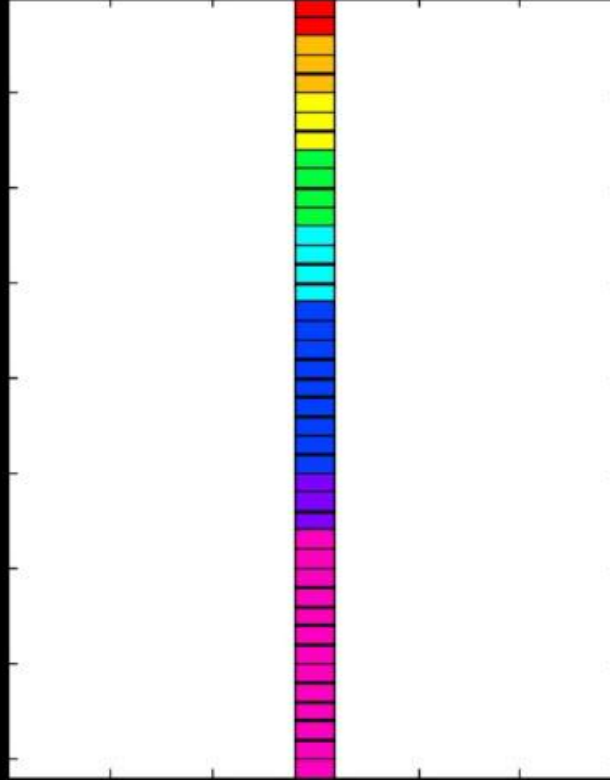
- Ward et al. (2008) *Quorum decision-making facilitates information transfer in fish shoals*. PNAS 105(19), 6948-6953.
- Couzin et al. (2005) *Effective leadership and decision making in animal groups on the move*. Nature 433, 513-516.

... markets are no different

If prices are synchronized, then only a small number of informed traders are needed for prices to correctly adjust.



(A) Smoothed price trajectories of 40 large-cap US stocks in 30 second intervals from 1pm to 4pm on Feb. 25, 2010. (B) Tracked motion of schooling mosquitofish.



Price movements of 40 large-cap US stocks in one minute intervals on Feb. 24, 2010. Colors correspond to market sector.

Synchronization increases efficiency



(1) Country X is likely to default.

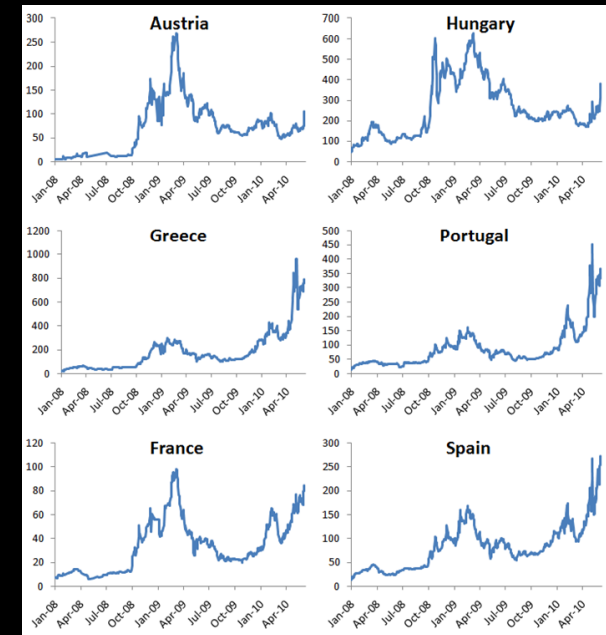


(2) Firm A buys securities that track probability of default.



(3) These security prices increase.

(4) If markets are synchronized, the prices of all other securities adjust.



- Prices are more accurate
 - An investor who purchases or sells any security in the market receives a more accurate price.
- Transaction costs are reduced
 - Liquidity providers are more confident in market prices and require less of a price concession to transact with an order.

... but who loses?



Country X



Country Y

Firm A



Firm B



- Imagine that country X and Y are related, so that when X is likely to default so is Y.
- Firm A follows X and Firm B follows Y.

... but who loses?



HFT



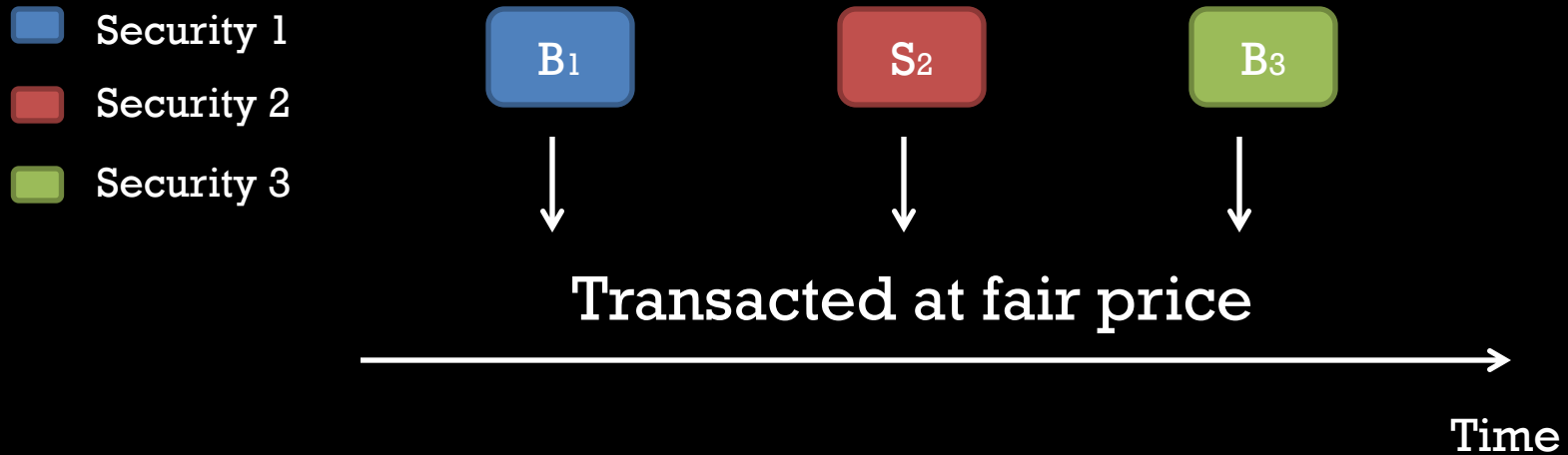
Firms A and B make less money when prices are tightly synchronized because they now must compete with each other when processing information.

Modelling cross-asset price discovery



Manoj Narang, CEO Tradeworx

Model

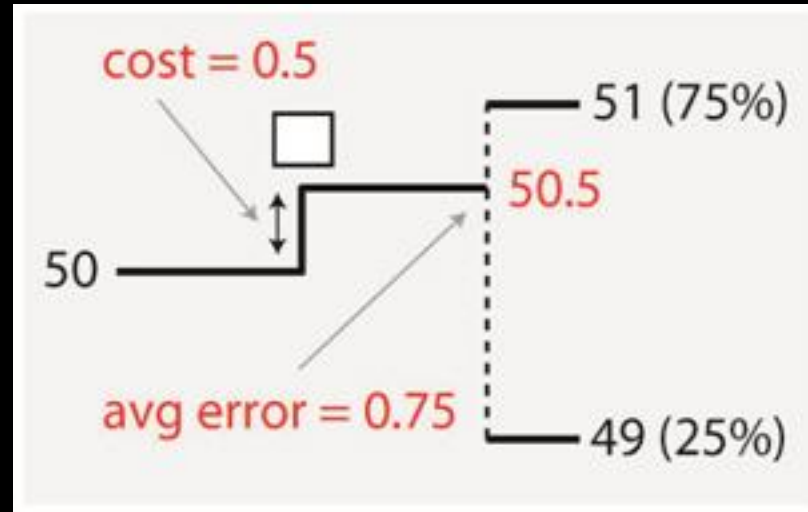


- n securities trade asynchronously over a single period.
- One unit-sized order to buy or sell is submitted for each security (B_i or S_i). $P(B_i) = P(S_i) = 0.5$
- Orders are immediately transacted by liquidity providers at the fair price, i.e., at the expected future price of the security.

Model

- The final price of a security increases or decreases by δ_i with equal probability.
 $P(+\delta_i) = P(-\delta_i) = 0.5$
- Orders are correlated with final price change,
 $P(B_i | +\delta_i) = \phi_i > 0.5$
- Final price changes of securities are correlated, ρ_{ij}

Example



Buy order is submitted

Original price = 50

Final price = 49 or 51 ($\delta_i = 1$)

$P(B_i | +\delta_i) = \phi_i = 0.75$

$P(+\delta_i | B_i) = P(B_i | +\delta_i) P(B_i) / P(+\delta_i) = 0.75$

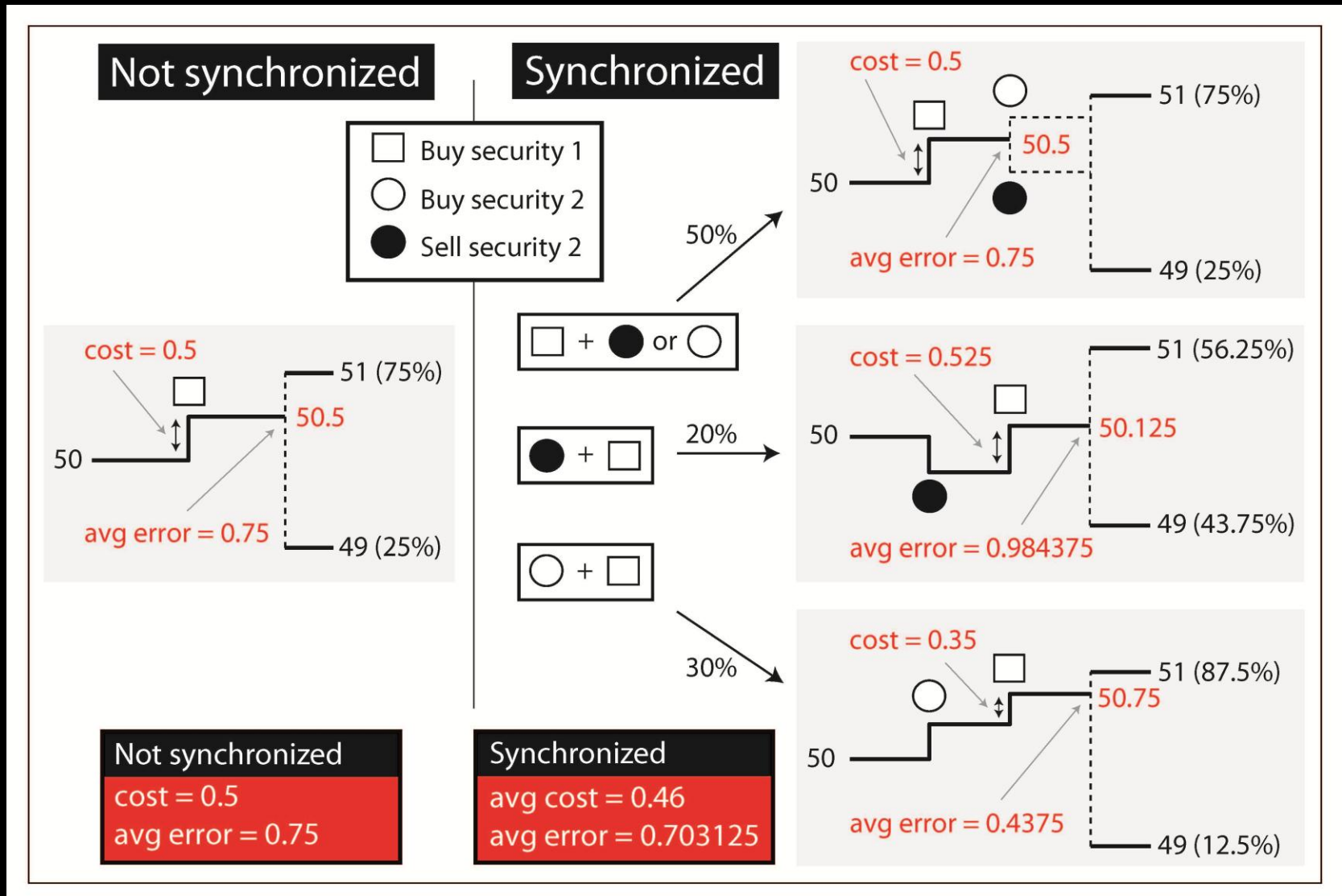
Cost = 0.5

Average error = 0.75

Adding a second security

- A second security is added with the same properties as the first.
- Final prices are correlated with $\rho_{ij} = 0.8$
- What happens to the average cost and pricing error for the buy order?

Synchronization increases efficiency



Equations

$$\begin{aligned}\mathcal{P}(B_2|B_1) &= \frac{\mathcal{P}(B_2, B_1)}{\mathcal{P}(B_1)}, \\ &= \frac{1}{\mathcal{P}(B_1)} \sum_{x_1, x_2} \mathcal{P}(B_2, B_1|x_1, x_2)\mathcal{P}(x_1, x_2), \\ &= \frac{1}{\mathcal{P}(B_1)} \sum_{x_1, x_2} \mathcal{P}(B_2|x_2)\mathcal{P}(B_1|x_1)\mathcal{P}(x_1, x_2), \\ &= 0.60.\end{aligned}$$

$$\begin{aligned}\mathcal{P}(S_2|B_1) &= \frac{\mathcal{P}(S_2, B_1)}{\mathcal{P}(B_1)}, \\ &= \frac{1}{\mathcal{P}(B_1)} \sum_{x_1, x_2} \mathcal{P}(S_2, B_1|x_1, x_2)\mathcal{P}(x_1, x_2), \\ &= \frac{1}{\mathcal{P}(B_1)} \sum_{x_1, x_2} \mathcal{P}(S_2|x_2)\mathcal{P}(B_1|x_1)\mathcal{P}(x_1, x_2), \\ &= 0.40.\end{aligned}$$

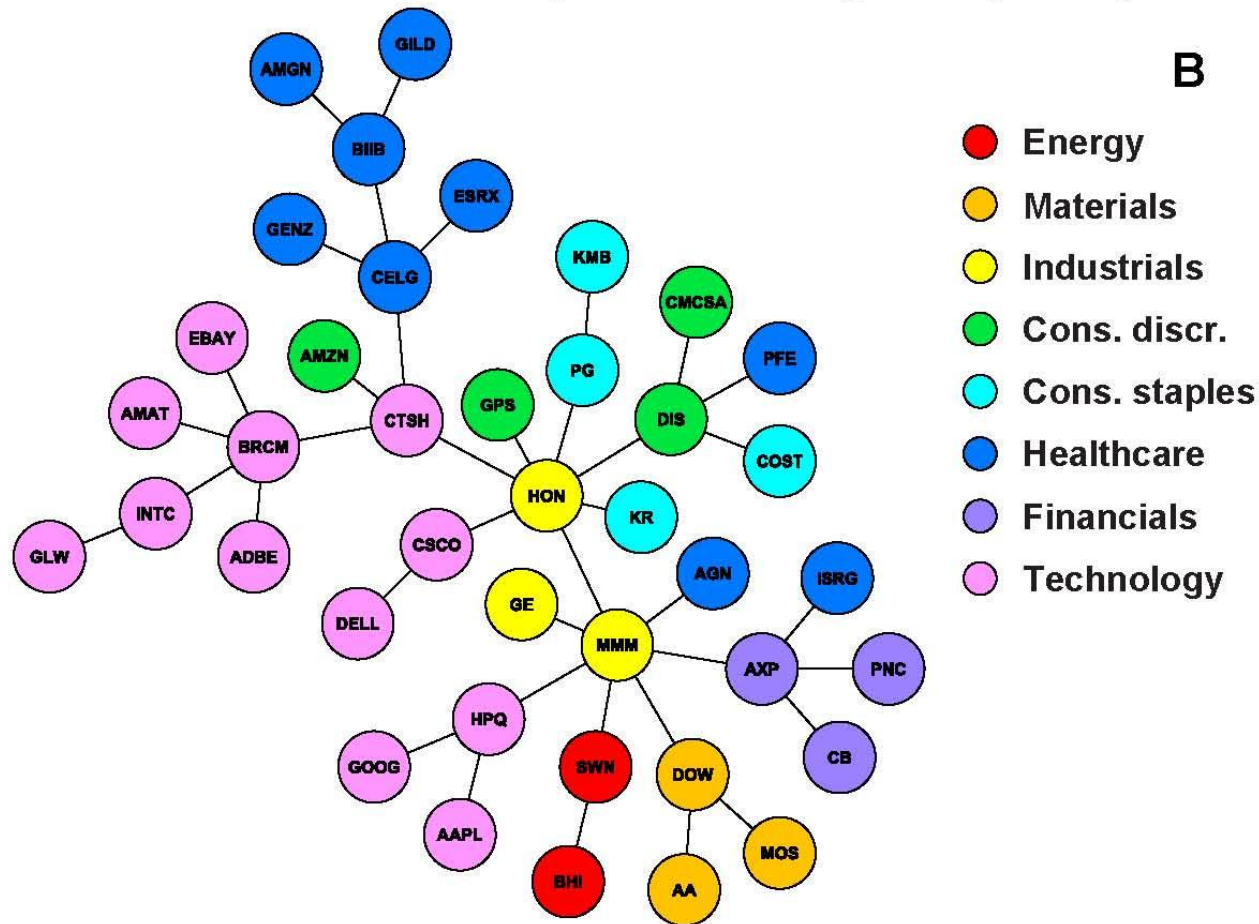
$$\begin{aligned}p_1 &= E[x_1|B_1, B_2], \\ &= x_1^+ \mathcal{P}(x_1^+|B_1, B_2) + x_1^- \mathcal{P}(x_1^-|B_1, B_2), \\ &= 51 \times 0.875 + 49 \times 0.125, \\ &= 50.75\end{aligned}$$

$$\begin{aligned}p_1 &= E[x_1|B_1, S_2], \\ &= x_1^+ \mathcal{P}(x_1^+|B_1, S_2) + x_1^- \mathcal{P}(x_1^-|B_1, S_2), \\ &= 51 \times 0.5625 + 49 \times 0.4375, \\ &= 50.125\end{aligned}$$

What should worry regulators?

- When prices are tightly connected, errors can quickly propagate through the financial system.
- HFT firms are run by scientists/engineers, are they enforcing spurious relationships?

Plausible relationships exist at high frequency



Minimum spanning tree derived from the 30 second correlation matrix for the 40 large-cap stocks. The ticker for each stock is shown on the corresponding node, and nodes are color-coded according to GICS sector (Gerig, 2012).

Conclusions

- There are, on average, over one thousand transactions per second in US equities alone during the trading day.
- High-speed computerized trade is needed to keep prices connected.
- Markets are most efficient if prices are updated at timescales corresponding to the frequency of trade: currently milliseconds to microseconds.
- HFT activity requires careful monitoring to ensure that:
 - errors do not propagate from one security to the rest of the market.
 - that correct relationships between securities are being enforced.