Game Theory of Finance

Confidence, Liquidity, and Financial Crises

David McAdams
Professor of Economics
Fragile “Strength” at Bear

“Our balance sheet, liquidity, and capital remain strong.”

- Bear Stearns CEO Alan Schwartz, Friday March 7th, 2008

... 7 days later, on March 14th, Bear received a $25 billion federal bailout ...
Stuck in Palm Beach

- From Thursday, March 6th through Monday, March 10th, Bear CEO Alan Schwartz was in Palm Beach, Florida, at client-industry conferences:
  - telecommunications [Verizon]
  - media [Disney]

- Why didn’t he go back to New York to manage the unfolding crisis?!?
“No Cause for Alarm”

- Leaving in a hurry could have caused Iger to grow concerned
- ... with good reason, if no one leaves in a hurry unless it’s REALLY bad!!

“Troubles interrupt Alan Schwartz's meeting with Disney's Robert Iger” (WSJ 2008)
This Talk’s Main Theme: Hidden Information in Finance

- Hidden info & **confidence**
  - Application: Bear Stearns
  - **Application: dividends**

- Hidden info & illiquidity
  - Application: toxic-asset trading
  - Application: high-speed trading
The Dividend Puzzle

“It would be uneconomic as well as pointless [for firms to pay dividends and raise capital simultaneously]”

- Merton Miller and Kevin Rock, 1982
Dividends

- Why might it be make sense for a firm to issue a dividend *and* for investors to view this positively?
- Why don’t firms change their dividends more often?
Dividends

- Why might it be make sense for a firm to issue a dividend and for investors to view this positively?
- Why don’t firms change their dividends more often?

For more on dividends, see e.g. “Managerial Responses to the May 2003 Dividend Tax Cut” by Brav, Graham, Harvey, and Michaely (2008)
This Talk’s Main Theme: Hidden Information in Finance

- Hidden info & **confidence**
  - Application: Bear Stearns
  - Application: dividends

- Hidden info & **illiquidity**
  - Application: toxic-asset trading
  - Application: high-speed trading
Live Game

Asset Trading
Asset Trading Game

- Two types of asset: Good ("Peach") and Bad ("Lemon")
  - 60% of sellers have Good asset
- Each Buyer wants at most one asset
  - Good asset worth $20 to Buyers but worth only $10 to Sellers to keep
  - Bad asset worth $0 to both
- No future opportunity to trade
Asset Trading Game

The game has two phases:

1. **Bilateral exchange**
   - free-mixing (walk around)
   - Buyer can pay $4 to verify asset quality
   - once a Buyer-Seller pair agrees on a price, they are “out of the market”

2. Market book
Asset Trading Game

The game has two phases:

1. **Bilateral exchange**

2. **Market book**
   - anyone who did not trade in phase #1 can submit buy/sell order into the book
   - trades at “market-clearing price”
   - [winning buyers draw assets from hat]
What is liquidity?

**liquid asset**

/ˈlɪkwɪd ˈæsɛt/

noun FINANCE

an asset that can be converted into cash in a short time, with little or no loss in value.
Sources of illiquidity

- An asset can be illiquid for either of two (very different) reasons

1. inherently thin market, i.e. trading partners are hard to find
Sources of illiquidity

- An asset can be illiquid for either of two (very different) reasons

1. *inherently thin market*, i.e. trading partners are hard to find

2. *lemons market*, i.e. plenty of counterparties but everyone’s afraid of hidden “lemons”
What Price for Lemons?

At what price could assets sell?

- $0?
  - who would sell at that price?

60%  
$20 | $10

40%  
$0 | $0
What Price for Lemons?

At what price could assets sell?

- $0?
  - only Lemons would be offered for sale at $0
  - ... and buyers are willing to pay that price for Lemons
  - So, yes, a market could exist in which only the very worst assets trade, at prices reflecting their true toxicity

60% $20 | $10

40% $0 | $0
What Price for Lemons?

At what price could assets sell?

- $0 ✓
- between $0 and $10?
  - only Lemons would be offered at any price less than $10
  - ... but buyers are only willing to pay $0 for Lemons

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<thead>
<tr>
<th>60%</th>
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What Price for Lemons?

At what price could assets sell?

- $0  ✔
- between $0 and $10  ✗
- between $10 and $12

- Lemons & Peaches both offered
- ... and buyers are willing to pay up to $12 for an average asset [i.e. 60% Peach]
What Price for Lemons?

At what price could assets sell?

- **$0** ✔
- **between $0 and $10** ✗
- **between $10 and $12** ✔
- **more than $12** ✗

Buyers aren’t willing to pay more than $12 unless asset can be *proven* to be a Peach.
Lemons and Illiquidity

The presence of lemons can create illiquidity in two ways:

1. **unwillingness to trade**
   - imagine $Pr(\text{Lemon}) > 50$
   - Average asset now worth less than $10 \rightarrow \text{no price at which}
     - a) Peach owners willing to sell
     - b) Buyers willing to buy
Lemons and Illiquidity

The presence of lemons can create illiquidity in two ways:

1. **unwillingness to trade**
   - or, imagine “dynamic game” in which willingness to sell right away signals low quality
   - no one ever “moves first” and so no deals ever get done

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Lemons and Illiquidity

The presence of lemons can create illiquidity in two ways:

2. **verification costs**
   - only Peach owners willing to underwrite / submit to costly verification of their quality
     - *(Peach gets $16 rather than $12!)*
   - Peaches trade, but only in bilateral-exchange market
Buying Up a Mystery Fruit

What if, rather than having a known mix of Good and Bad assets, we have one asset of unknown quality?

- All sellers have same “mystery asset” and know its quality
- Buyers all have same belief about how likely it’s a Lemon
Buying Up a Mystery Fruit

For a bit more realism, imagine this asset is a $100 bond whose market is completely frozen due to uncertainty about its probability “p” of default

\[ \text{true value} = 100 \times (1 - p) \]
For a bit more realism, imagine this asset is a $100 bond whose market is completely frozen due to uncertainty about its probability “p” of default.

- **true value** = $100 * (1-p)
- **liquidity needs** create incentive to sell and differs across sellers based on financing, etc.
Troubled Asset Relief Program

In October 2008, Congress authorized U.S. Treasury to purchase or insure up to $700 Billion of “troubled assets”

What’s the most effective way to use these funds?
“Lifelong conservatives with careers of faithful adherence to free market principles have seen those careers wrecked this year, and no issue looms larger in their downfall than TARP.”

- Ron Elving, NPR, 2010
Political vs Economic Objectives

“It wasn't fair. But it was necessary.”

- Timothy Geithner, Treasury Secretary, 2010
“I'll leave history to the historians ... I did the best I could to prevent the collapse of the financial system.”

- Henry Paulson, former Treasury Secretary, speaking in 2010
How Much Did TARP Cost? (& Was It a Good Deal?)

- TARP’s estimated cost was significantly less than many think:
  - $700 Billion originally authorized BUT...
  - only about $430B disbursed AND, with repayments,
    - 2010 estimated cost of $66B [CBO]
    - 2012 estimated cost of $24B [CBO]
A Model of Toxic Assets

KEY ASSUMPTIONS

- Assets complex, hard to evaluate
- Assets owners understand quality better than non-owners (including Treasury Dept)
- Some asset owners have idiosyncratic need to sell, and this “liquidity need” varies across asset owners
In an Ideal World ...

If asset quality were observable

- **to other market participants**: those who need most to trade would find willing buyers at close to true value

- **to Treasury Dept**: Treasury could facilitate trade by “labeling” assets by true quality [much like credit agency]
  - ... or earn profit (while creating liquidity) by “buying low & selling high”
I will focus on three options:

1. **TOXIC-ASSET AUCTION** to identify and buy “most toxic assets”
2. **BILATERAL NEGOTIATION**
3. **ASSET-CLASS AUCTION** to identify price for each asset class
Rules: Toxic-Asset Auction

- Asset owners decide at each price which assets they are willing to sell

- Price falls until offered assets can be purchased with TARP budget
Illustration of Play: Toxic-Asset Auction

<table>
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All asset owners willing to sell at 100 ("par")
- TARP budget too small to buy all offered assets
- Price is lowered
Illustration of Play: Toxic-Asset Auction

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Asset owners willingness to sell depends on true value:
- below 75 → sell
- above 75 → sell if large enough liquidity need
Illustration of Play: Toxic-Asset Auction

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As price is lowered, quality of offered assets gets worse and worse ...
Illustration of Play: Toxic-Asset Auction

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Finally a price is reached ($25) where TARP budget is enough to buy all offered assets.
How Did We Do?
(1) Cost to Taxpayer

TARP makes profit on these assets, by creating market for firms with pressing liquidity needs.

TARP hands windfall to owners of the most toxic assets.

#assets purchased
How Did We Do?
(2) Generating Liquidity

- Very worst assets have been removed from firms’ books
- BUT hidden-info problem remains for all other assets
- Expect “lemons market” to continue, unless TARP budget sufficiently massive.
Three Market Design Options

I will focus on three options:

1. **TOXIC-ASSET AUCTION** to identify and buy “most toxic assets”
   - *worst*; guaranteed to overpay while doing little to solve hidden-info problem

2. **BILATERAL NEGOTIATION**

3. **ASSET-CLASS AUCTION**
I will focus on three options:

1. **TOXIC-ASSET AUCTION**

2. **BILATERAL NEGOTIATION**
   - *chosen*; takes advantage of Treasury expertise in evaluating assets; *could* allow US to profit while *partially* solving hidden-info problem

3. **ASSET-CLASS AUCTION**
Three Market Design Options

I will focus on three options:

1. **SINGLE AUCTION**
2. **BILATERAL NEGOTIATION**
3. **ASSET-CLASS AUCTION** to identify price for each asset class
Rules: Asset-Class Auction

- Treasury groups “similar” assets together in separate auctions

- Commits to purchase same percentage of each asset class
  - this % determined by budget & bids

- KEY IDEA: Harnesses within-asset-class competition
Play: Asset-Class Auction

- Consider asset-class with default-rate $p = 50\%$
  - “true value” = 50
  - those with liquidity needs willing to sell for less than 50

- What’s going to happen in the auction?
How Did We Do?

(1) Cost to Taxpayer

- PROFIT to the taxpayer

- TARP budget

- 45% asset-class purchased
How Did We Do?
(2) Generating Liquidity

TARP creates value for financial institutions by allowing those with pressing liquidity needs to unload assets anonymously (at a modest loss).
How Did We Do?

(2) Generating Liquidity

- All asset-classes priced so as to reveal hidden information
  - e.g. price = 45 for assets whose true value is 50 → now everyone knows this asset worth *at least* 45

- Addresses hidden-info “lemons problem” for all asset classes
Three Market Design Options

I will focus on three options:

1. **SINGLE AUCTION**

2. **BILATERAL NEGOTIATION**

3. **ASSET-CLASS AUCTION** to identify price for each asset class

   - *best*; allows US to profit while solving hidden-info problem, despite not using Treasury expertise
This Talk’s Main Theme: Hidden Information in Finance

- Hidden info & **confidence**
  - Application: Bear Stearns
  - Application: dividends

- Hidden info & **illiquidity**
  - Application: toxic-asset trading
  - Application: high-speed trading
Brief History of High-Speed Trading (aka “HFT”)

- 1975: National Market System (NMS) Regulations mandate interconnected exchanges
  - “electronic communication networks” (ECN) emerge as players offering “alternative trading systems” (ATS)
Brief History of High-Speed Trading (aka “HFT”)

- 1975: Reg NMS → birth of electronic communications networks (ECNs)
- 1997: SEC Limit Order Display Rule to stop corrupt broker “interposition”
(Illegal) Interpositioning

CLIENT

$96

BROKER

ill-gotten $1

$95

MARKET

“I’m willing to pay up to $100.”
Brief History of High-Speed Trading (aka “HFT”)

- 1975: Reg NMS → birth of electronic communications networks (ECNs)
- 1997: SEC Limit Order Display Rule to stop corrupt broker “interposition”
  - ECNs specialize in displaying “national best bid & offer (NBBO)” and aiding new breed of “algorithmic trader”
Brief History of High-Speed Trading (aka “HFT”)

- 1975: Reg NMS → birth of ECNs
- 1997: Display Rules → rise of ECNs
- 2005: Reg NMS revised
  - “Order Protection Rule:” trades must execute at best price available [ignoring factors such as counterparty reliability, transaction speed, etc]
  - **new interposition opportunity** for “high-frequency trader” with fastest info feeds and order generation
Order Protection Rule 611

“In theory, this rule should help investors get the best price in the market, regardless of where an order initially is routed. In practice, high-frequency traders have undermined the ability of others to secure the best price ...”

- Haim Bodek, founder of Trading Machines LLC, 2012
How high-frequency trading can cut orders off

Orders placed in New York take time to get to all the major exchanges. Fast high-frequency trading services see the order at the BATS exchange and intercept it at more distant ones.
The Thirty-Millisecond Advantage

In high-frequency trading, computers buy and sell stocks lightning fast. Some marketplaces, like Nasdaq, often offer such traders a peek at orders for 30 milliseconds — 0.03 seconds — before they are shown to everyone else. This allows traders to profit by very quickly trading shares they know will soon be in high demand. Each trade earns pennies, sometimes millions of times a day.

9:31:00.00 A.M.
INVESTOR SUBMITS ORDER
A slow-moving mutual fund submits an order to purchase 5,000 shares of company XYZ.

9:31:00.01 – 9:31:00.03 A.M.
FAST TRADERS GET TO PREVIEW ORDERS
Before that order is sent to the broad marketplace, it is routed to high-frequency traders for 30 milliseconds.

9:31:00.05 A.M.
TRADERS BUY
The high-frequency traders, knowing that an order is coming, flood the market with buy orders, scooping up all available shares of XYZ at $21.00.

9:31:00.30 A.M.
MUTUAL FUND ORDER EXECUTED
The mutual fund order hits the marketplace, and the high-frequency traders sell their shares at $21.01, pocketing the 1-cent profit — for a total of $50 in this case.

THE NEW YORK TIMES
High Frequency Trading - C++ Prop Developer 175-220K Base (280-350 TC) Top performing Investment Bank
New York, NY

High Frequency Trading - C++ Prop Developer
175-220K Base (280-350 TC)
Top performing Investment Bank
New York, NY

My client is a Global Director of High Frequency Trading at a top performing bank. This team in particular is in charge of building a sub-10 microsecond tick to trade high frequency low latency platform. The Director is looking to expand the group rapidly and will be adding a number of top-notch candidates to work on a next-generation high performance platform.

This individual would ideally be coming from a buy-side firm as he/she will serve as an expert on the subject matter and collaborate with teams across the globe. This group is in midst of building out a new platform, so the individual will have plenty on his/her hands from day one. This is a fantastic opportunity for a developer who wants to help design and architect a cutting edge platform and work in a group with brilliant engineers.
(Legal) High-speed trading

$21.01 → $21.00

BUYER

HIGH-SPEED TRADER

profit $.01

Market

Note: interpositioning does not create new trades ... only extracts some of the value from trades that would have happened anyway
But What About Liquidity?

“The HFT guys are providing liquidity ... In the New York stock markets they’re just over 50% of all trading right now. So they’re obviously 50% of all the liquidity. Which means that they’re also 50% of what reduces the spread on those markets.”

- Tim Worstall in Forbes, March 2014
Reminder: What is liquidity?

**liq·uid as·set**

/ˈliːkwɪd ˈæsɛt/

noun FINANCE

an asset that can be converted into cash in a short time, with little or no loss in value.
Volume ≠ Liquidity

Imagine that every legitimate trade were interposed exactly once by a high-speed trader.

What would HFT volume % be?
Volume ≠ Liquidity

- You guessed it ... 50%
- But interposers do not create liquidity!! In fact, their presence can only increase bid-ask spreads.
Why is there a bid-ask spread in the first place?

- Bid-ask spreads can arise for two basic reasons:
  - market-maker market power
  - market-maker lemons problem
The Market-Maker’s Lemon

“I feel like buying today”

“The price is about to jump $1”

CURRENT PRICES

ASK $20.10

BID $20.00

IF noise trader arrives, market-maker EARN $0.10
The Market-Maker’s Lemon

“I feel like buying today”

NOISE TRADER

“The price is about to jump $1”

INFORMED TRADER

CURRENT PRICES

ASK $20.10
BID $21.00

MARKET MAKER

IF informed trader arrives, market-maker LOSES $0.90
The Market-Maker’s Lemon... and High-Speed Traders

Current Prices

- **ASK**: $20.10
- **BID**: $21.00

**Informed Trader**

- “The price is about to jump $1”

**High-Speed Trader**

- “The price is about to jump $1”

**Market Maker**

- If informed **OR** high-speed trader: market-maker loses $0.90
HFT → Less Liquidity

“The high-frequency arms race is not only socially wasteful – a Prisoners’ Dilemma built directly into the market design – but its cost is ultimately borne by investors via wider spreads and thinner markets.”

- “The High-Frequency Trading Arms Race,” 2014 working paper by Eric Budish, Peter Cramton, John Shim
HFT as Prisoners’ Dilemma

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<tr>
<td>Don’t</td>
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<td>less jailtime</td>
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HFT as Prisoners’ Dilemma

- Utilize HFT strategies
  - HFT
  - Don’t

- Don’t
  - less liquidity
  - more liquidity

How can we escape this Prisoners’ Dilemma? [Lesson from cigarettes!]
Cigarette Advertising on TV

- All US tobacco companies advertised heavily on television

1964
- Surgeon General issues official warning
  - Cigarette smoking may be hazardous

1967
- FCC mandates matching anti-smoking messages on television, after any tobacco ad

1970
- Companies strike agreement
  - Carry the warning label and cease TV advertising in exchange for immunity from federal lawsuits.
What Happened?

- You might expect the TV-ad ban to have hurt the cigarette industry.

- In fact, the ban was a huge boon

- From 1970 to 1971:
  - cigarette advertising decreased by $63 million, while
  - *profits rose by $91 million*
Advertising ... as Prisoners’ Dilemma

- Both firms have a dominant strategy to advertise.
- Both are worse off when both advertise, as market-stealing “cancels out”.

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<th>Philip Morris</th>
<th>Reynolds</th>
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<tr>
<td>Ad</td>
<td>30, 30</td>
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<td>Not</td>
<td>60, 20</td>
<td>50, 50</td>
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</table>
Changing the Game thru Regulation

The agreement with the government forced the firms not to advertise.

The preferred outcome (No Ad, No Ad) then was all that remained feasible.
Is it feasible to solve HFT Prisoners’ Dilemma by similarly banning or blocking high-frequency trading?  
... in a way that does not interfere with proper functioning of the markets ...
Market-Design Solution: Batch Auctions

- Batch auctions open trading every morning on NYSE
- bids gathered overnight are executed to determine opening price [HERE $12]

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<tr>
<th>BIDS [TO BUY]</th>
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<tr>
<td>ASKS [TO SELL]</td>
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<td>$11</td>
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Market-Design Solution: Batch Auctions

Imagine conducting such an auction every [deci]second, to clear all trades nationwide for each asset

- *fair* [all trades at same price]
- *still rewards those with best information (including “market makers”)*
  - BUT no longer any gain from gathering info that will become available to everyone within the next blink of an eye
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- Hidden info & **illiquidity**
  - Application: toxic-asset trading
  - Application: high-speed trading
Want More Game Theory?

1. **Spring 1 Elective: “Game Theory for Strategic Advantage” (GTSA)**
   - MGRECON 784

2. gamechangerfiles.com
Student Praise for GTSA

- “New concepts, new frameworks, new way of thinking → Phenomenal!!”
- “I loved the games, excitement, and engagement with the rest of our business education. Awesome class!!”
- “Very relevant to any career.”
- “Incredibly effective.”
- “We will apply this in real life.”
Want More Game Theory?

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2. gamechangerfiles.com
Game-Changer Files based on Student Final Projects

- “Addicts in the Emergency Department.” How can hospitals address the huge wave of drug addicts seeking painkillers?
  - 2012: Alex Kerr, Blake Lloyd, Dan Reese, Sarah Schiavetti
  - *Now a Game-Changer File Video!!*

- “A Better Best Buy.” How can Best Buy overcome the threat posed by “showrooming”?
  - 2014: Lynn Liao, Manav Tandon, Derek Song, Jonathan Wang
  - *Now a Game-Changer File Video!!*
“Instagram Commerce.” How online fraud could be just the opening Facebook needs to enter and win in online commerce in Thailand.

- 2014: Lada Mahapun, Matt Hamilton, Kamonson Ratitong, Nawat Vongwattanakit
- Now a Game-Changer File Video!!

“Saving the Wild Rhino.” Rhino poaching has increased ~10000% over the past ten years. How can we save rhinos from extinction?

- 2014: Brett Farley, Andrei Horga, Reza Logday, Tina Retief
- Soon to be a Game-Changer File Video!!
THANK YOU!!