Model Specification Error with High-Speed Computational Propagation Seen in the Subprime Meltdown

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Rice University
The capacity to wreak destruction with your models provides the ultimate respectability - E. Derman

We do not know the web of interconnections between banks that has been established through derivatives. The market is losing transparency and we do not know who is dependent on whom anymore. Now we will only know after the fact, and by then it could be too late. - A. Lamfalussy, GM, BIS

26 year olds with computers are creating financial hydrogen bombs." - F. Rohatyn (Lazard Feres)
• Laplacian Dæmon – 19th century ideal
  – Perfect knowledge of the past and the system → perfect prediction

• Poincare complication (per Mirowski, 1990)
  – Imperfect knowledge of past (minor errors)
    → wildly discrepant future predictions
  – 60 years before Mandelbrot
Axiomatic Model

• Plato
  (333 BCE; Platonic Ideal Form)

• Gauss (1809)-Pearson (1900) Decomposition
  \[ X = \mu + u \]
  \[ u = "\text{noise}" \]

• Engenders many models for evaluation.
  \[ Y = x^{.95} \text{ instead of } y = x \]
• Deterministic growth
• Economics and Finance
• Only noise is precision
• Mathematical economics (Thanks to Pareto)
  – “(1) Use mathematics as shorthand language, not an engine of inquiry. (2) Keep to them till you have done. (3) Translate to English. (4) Illustrate by germane examples. (5) Burn the math. (6) If 4 fails burn 3. This I do often.”
• Knight/Keynes formalized risk vs. uncertainty by 1921
• Risk → data → computational requirements
• Econometrics = Mathematical economics + statistics
• $E[\eta(Y)] = X\beta$
<table>
<thead>
<tr>
<th>OBJECT</th>
<th>DESCRIPTION</th>
<th>APPROX. DISTANCE</th>
<th>GRID BEARING</th>
<th>DEGREES</th>
<th>MINUTES</th>
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<td>LEFT EDGE OF CORRUGATED IRON SHED.</td>
<td></td>
<td>1750 x</td>
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<td>26</td>
<td></td>
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<tr>
<td>RIGHT EDGE OF SMALL SHED.</td>
<td></td>
<td>170 x</td>
<td>32</td>
<td>40</td>
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<tr>
<td>CENTRE OF TALL CHIMNEY ON SKYLINE.</td>
<td></td>
<td>4000 x</td>
<td>74</td>
<td>54</td>
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<td>LEFT EDGE OF HOUSE IN FRONT OF WOOD.</td>
<td></td>
<td>250 x</td>
<td>168</td>
<td>55</td>
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PREPARED BY Gay Wood J.J.

CHECKED BY L.W. Smith

May 16, 2012
• Physics Model
• Some statistics
  – Non-standard conditions
  – Probable error of the gun
• Range/Firing tables
• M3/M4 gun data [analog] computer
• Computes all data:
  – AZ, EL, fuse time
• Continuous firing
• NOT manual “computerization”
  – New approach
  – Better accuracy
  – NEEDED DATA
The Probability Approach in Econometrics (Havelmo 1944)

- Tool to evaluate mathematical theories of economic actors
- Still based on Knight’s concept of risk
  - Distribution(s) known
    - Outcomes known
    - Law known
- Precise statistical analysis
- John von Neumann (Game Theory)
• New Physics, including statistical physics
• Delivery includes artillery model
• Solved the fire control and noise problems
• J. Von Neumann/Metropolis: Marchant calculator → ENIAC
Electronic Numerical Integrator & Calculator
• M. Friedman (1953)
  – Rational speculator and positivism
• Arrow and Debreu construct (1954)
• Modigliani & Miller (1958)
  – Re-proved J.B. Williams (’38) result
  – Used “arbitrage” and “equilibrium” arguments
  – Therefore *scientific*
• H. Markowitz (1952, 1959)
  – MPT and equilibrium concepts
  – Diversification (e.g., into unknown foreign credit markets or sovereign CDS!)
• Roberts and Cootner codify random walk concepts (1959, 1964)

• MLPFS funds CRSP at U. Chicago (1960)
  – J. Lorie and L. Fisher

• CAPM (Treynor 1962; Sharpe ’64, Lintner ’65 and Mossin ‘66)

• 60’s-70’s MSI/LSI (e.g., TI’s 1973 SR-50 for $150)

• 1970:
  – Box & Jenkins *Time Series Analysis*
  – RW generalized to EMH (Fama)
  – First MBS (GNMA)
  – 1st Draft of BSOPM to *J. Pol. Economy*
\[ C = Se^{-q\tau} \Phi(d_1) - Xe^{-r\tau} \Phi\left(d_1 - \sigma \sqrt{\tau}\right) \]
• Developed for the “sell-side”
• Eliminates differing views on growth of an underlying instrument.
  – E.g., AAPL: $\mu, \sigma \neq (60\%, 22\%), \mu = r = 0$

“Can sell as much risk as the client wants w/o taking on risk yourself”  -Emmanuel Derman
Many of these models provide the illusion of certainty. There is a kind of assurance that ultimately can't be satisfied." - Henry Kaufman

An approximate answer to the right problem is worth a good deal more than an exact answer to an approximate problem. -John Tukey

Statisticians, like artists, have the bad habit of falling in love with their models. -and- All models are wrong, but some are useful. -George E. P. Box
A Routine Day

• For non-quantitative investors

Dow Jones Industrial Average - Week of May 3, 2010

<table>
<thead>
<tr>
<th></th>
<th>Open</th>
<th>High</th>
<th>Low</th>
<th>Close</th>
<th>Vol (B Sh)</th>
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<tr>
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<td>11,203</td>
<td>11,004</td>
<td>11,152</td>
<td>4,938</td>
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<tr>
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<td>11,149</td>
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<td>10,754</td>
<td>10,868</td>
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<td>5/6/10</td>
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<td>10,926</td>
<td>9,787</td>
<td>10,520</td>
<td>10,618</td>
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<tr>
<td>5/7/10</td>
<td>10,519</td>
<td>10,622</td>
<td>10,222</td>
<td>10,380</td>
<td>9,473</td>
</tr>
</tbody>
</table>

• Vol: 98.5\textsuperscript{th} percentile, but only 1.4\sigma

• Note low
A Flash in The Market

Stock markets plunged suddenly on May 6 of this year and gained speed as computer programs prevented losses. But almost as quickly, the market recovered much of the decline.

1 1:00 Volatility in some stocks increases in a down market.

2 2:30 Unusually nervous trading pushes overall volatility up sharply; the Dow is down 2.5 percent.

3 2:32 A program to sell $4.1 billion in E-Mini futures starts; other traders react by starting to sell.

4 2:41 Selling in the futures market spreads to stocks; automated trading programs react to the sharp drops by shutting down.

5 2:46 After trading in E-Mini futures is paused for five seconds, alleviating the pressure to sell, the market begins to recover.
Observations

• E-mini ESM12: 2.8M OI, 2.5M vol.
• Automated sell algorithm targeting 9% prev. minute’s volume (75k, no $P,t$)
  – 3 that size that year (~$4M/pt, $4.1B notional)
  – Limit example took 5 hours
• Sell pressure absorbed by
  – HFT futures traders
  – Fundamental futures traders
  – X-mkt arbitrageurs ⇒ equities
    • Buy ESM10, sell SPY/equities
    • ETF’s/Index arbitrageurs → program sell stocks
Modeling Process

Requirements -> Specification -> Testing (non-op, subset) -> Deployment/Implementation -> Calibration

Requirements
Model Specification

- BSOPM
  1971-
  1973
• Testing (offline)

• Implementation
  – 1973 CBOE

• Calibration

• Stop Dev. Cycle
1973 CBOE standardizes and lists exchange-traded options

- Greatly reduces friction (spreads, fees)
- Backtest models COULD be more realistic

“Mayday” 1975 Retail equity commissions fully deregulated.

Frictions and efficiency improves

Mis-specification of returns distribution does not
• Financial Engineering discipline erupts

• Seeds sown for various financial crises and panics 1974-2012
• Based on:
  – Knightian risk
  – Arrow-Debreu state price approach
  – Existence of elementary tradeables
  – No-arbitrage and BS assumption sets
  – BS constructs:
    • ‘Equilibrium’ and the risk-free hedge
    • Closed-form “dynamics” of BS SDE
• FTAP-1 and FTAP-2
• Any position possible
Regime Changes

- Vast spread of computational power and ubiquitousness in 80’s-90’s
- Proliferation of OTC and ET derivatives
- Large-scale networking breakthroughs in 90’s-00-10’s in CONUS and the world
- Wild growth of mixed strategy hedge funds 00-10’s
- Direct access/HF market trading continued to eliminate arbitrage opportunities
• Asia and Russian Financial Crisis

4 Long Months in 1997

4 Long Months in 1998
“How do you explain to an innocent citizen of the free world the importance of a credit default swap on a double-A tranche of a sub-prime collateralized debt obligation”

-Ben Hockett
“Originate and Sell!”

FNM[A.OB], FRE[FMCC.OB], GNMA, FHLB

Domestic and other countries

Mutual Funds, Pension Funds, Insurance Funds, Hedge Funds, Investment Banks (BSC, LEH, MER, GS, MS, BOA, C, DB, UBS)
Securitization

• ABS/MBS
  – MBS (GNMA, 1970)
  – ABS (Cash Flow producing assets)
    • 1st Eurozone ABS – IKB 1924 (German war reparation payments)
    • Iceland’s fish privatization and securitizing of quotas in early 1970’s
    • First US ABS 1985
      – 1st Sperry timeshare leases
      – 2nd $60M CARS (auto receivables)
  • Credit card, HELOC, student, auto loans
  • Subprime loans (mortgage and non-mortgage)
Assumptions: Securitization rate 75%; Loan Performance Reporting rate: Prime and Alt-A: 75%, Subprime: 65%

Source: Credit Suisse Mortgage Strategy

Appearing in Transactions Interface 2012, Rice University, Houston, Texas

May 16, 2012
• CMO and CDO are bonds, with reference securities (underlying assets) of M’s or D’s
  – Can also have reference securities of other CDO’s/Synthetic CDO’s!
• CDS are Insurance on these bonds
• CDO:
  – AAA rated tranch might pay to buyer
    • 2% if based on “good” loan pool
    • it might pay 5% based on SP pool.
  – Buyer ponies up cash, receives fixed pmts

• CDS:
  – In good times
    • On AAA instruments buyer might pay 17 bps p.a. i.e., $1,700 per year on $1M underlying bond
    • No payoff, lose $170k on $100M face; repeat until can no longer stand this.
– Seller makes $170k per year with little risk of payout since AAA rated (“risk-free”)

• If things go wrong:
  – Underlying downgraded 30+%, might want to divest, but can’t due to illiquidity.
  – Seller could buy possibly back the CDS but now it is quoted at 3500 bps.
  – Buyer receives payment of downgraded portion (50, 70, 100%)

• In 11/2007, 5yr CDS on Italy sovereign debt could be bought for 15 bps.
• October 2011 price was 550 bps. (3666%)  
• May 13, 2012, price was 460 bps. (3066%)  
• **Greece CDS rates are 5496.7 bps** 5/12/12
• 1983 First CMO (First Boston/Salomon)
• 1985 First ABS (Sperry’s Leases)
• 1986 $50M Credit Card CDO
• 1987 AIG FP formed for Carpe Diem
• 1995 $30B in Subprime Loans (SP); 65% fixed-rate
• 1997 SP lenders fail in boom of ’97
• 2000 $130B SP → $55B CDO
• 2001 AIG FP doing $300M CDS per year (all-types), contributing 15% profit
• 2004 CDS on corporate bonds available
• 2005 SP back up and running; $625B SP → $507B CDO’s; 75% ARM’s
• 2004-2005 Various parties observed increase in SPM activity and growth of the SP ABS markets and wanted to short
  – Could not
  – No CDS on SP CDO
• 2005 Credit card delinquencies @ all-time high
• 5/19/05 CDS on SPD (CDO) available.
  – Only GS and DB interested; Burry was 1st “retail” customer. Insisted on collateral
  – BBB only (250bps); (AAA 20bps, A 50)
  – GS would do $5M in 6/05; By 7/05 offering $100M (not on other side! Found seller)
  – AIG FP was selling to GS for 12! $400M riskless profit/yr to GS
• 2006 Mid-2006 Bass’ Hayman Capital formed, amongst < 20 others
• 10/16/06 Cornwall buys its first CDS
• By 2/2007, Cornwall had $205M of CDS on AA tranches of SPD CDO’s.
• 1st half 2007 Dozens subprime companies, (long) FI hedge funds, and banks fail
• AA SPD CDO’s still quoted at 98!
• MLPFS reports record Π; DJIA breaks 14,000 on 7/19/07
• 8/1/07 “Last” SPD CDO CDS since BSC lawsuit.

“There can come a moment when you can't trade with a Wall Street firm anymore and it can come like that!” - Ben Hockett

• Week of August 5, 2007.
  – Cornwall closes $205M in SPD CDO CDS, avg. 4000 bps on 50 bps investment (80x)
• 8/31/07 Burry closes BBB’s at 8000
• Party is over
• Worst class of SPMB had a description:
  “interest-only, negative-amortization adjustable-rate subprime mortgage”

• What they needed and had manufactured by persistence
  “CDS on AA-rated CDO’s on BBB-rated SPMB’s”

• 8/31/07, 20 days after Cornwall sold their AA’s for 4100bps, Burry sold his BBB’s for 8500 bps to desperate Wall St. firms.
Back on Main St.

S&P 500

IB Damage done by EOY 2007; shakeout ensues:
Stocks Finally Caught Up
• For non-quantitative investors

SPX - Week of August 6, 2007

<table>
<thead>
<tr>
<th>SPX</th>
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<th>High</th>
<th>Low</th>
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<th>Vol (B Sh)</th>
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<td>8/6/07</td>
<td>1,433</td>
<td>1,468</td>
<td>1,427</td>
<td>1,468</td>
<td>5,067</td>
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<tr>
<td>8/7/07</td>
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<td>1,488</td>
<td>1,456</td>
<td>1,477</td>
<td>4,909</td>
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<td>8/8/07</td>
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<td>1,504</td>
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<td>5,500</td>
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<td>1,497</td>
<td>1,453</td>
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<td>5,890</td>
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<tr>
<td>8/10/07</td>
<td>1,453</td>
<td>1,462</td>
<td>1,430</td>
<td>1,454</td>
<td>5,346</td>
</tr>
</tbody>
</table>

• Not so for many hedge funds executing quantitative equity market-neutral strategies (Long/Short stocks)
• Huge problem with the equity hedge funds August 6-10, 2007

<table>
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<tr>
<th>Date</th>
<th>Open</th>
<th>Close</th>
<th>Δ</th>
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<tbody>
<tr>
<td>8/3</td>
<td>1433.1</td>
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<td>8/6</td>
<td>1433.04</td>
<td>1467.7</td>
<td>34.6</td>
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<td>8/13</td>
<td>1453.42</td>
<td>1452.9</td>
<td>-0.7</td>
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</table>

• Quantitative equity market-neutral, and stat arb funds all suffered major losses
• “What Happened To The Quants In August 2007?” – Andrew Lo and Amir E. Khandani, J.Inv.Mgt. 2007

• Near-destruction of many non-fixed income arbitrage funds Aug. 6-9, 2007

5σ

25σ
Week of 8/5/12

- Aug 5 – S
- Aug 6 – M
- Aug 7 – T
- Aug 8 – W
- Aug 9 – Th
- Aug 10 – F

Lo’s Question – FI Fund
Unwinding and Unraveling

MTM, Massive
liquidations/unwinding

MTM, cascading liquidations,
unusual losses

Perfect storm over, now calm
• Adverse risk spills over into unrelated sector

• Risk
  – Market
  – Credit
  – Liquidity
  – Moral hazard

• Yet, very few people aware of the contagion and its outcome; by Friday 8/10 all was well.
• Scientific analytics
• Pricing execution and optimization
• By 2004 IKB “could value a CDO down to the last basis point”

• In 2005, IKB’s US-trained Dirk Röthig denied better originator ID/CDO pricing tool at $6.5M (on book of $20B, $200M Π)
“The pointer can sometimes get stuck”

“Computers get it fast, but people can get it wrong”

“Umm, bogey at 14 nanoseconds”

“Better be right at light’s speed”
Acknowledgements
References


