On the Nature of Financial Risk: Why Risk is so Hard to Measure and why Risk Models Fail so Often

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Sciences Po and Bank of France seminar
May 6, 2015
The presentation is based on

- “Model Risk of Risk Models”, (2014) with Kevin James (PCA), Marcela Valenzuela (University of Chile) and Ilknur Zer (Federal Reserve)
- “Why risk is so hard to measure” (2015) with Chen Zhou, Bank of Netherlands and Erasmus University, 2015
- And several VoxEU.org bloggs
Some actual price series
Some actual price series
 Lets forecast risk
with “reputable” models that generally are accepted by the authorities and industry

- Value–at–Risk (VaR) and Expected Shortfall (ES)
- Probability 1%
- Using as model
  - **MA** moving average
  - **EWMA** exponentially weighted moving average
  - **GARCH** normal innovations
  - **t–GARCH** student–t innovations
  - **HS** historical simulation
  - **EVT** extreme value theory
- Estimation period 1,000 days
## Risk for the next day \((t + 1)\)

Portfolio value is 1000

<table>
<thead>
<tr>
<th>Model</th>
<th>VaR</th>
<th>ES</th>
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<tbody>
<tr>
<td>HS</td>
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<td>EWMA</td>
<td>1.59</td>
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<td>1.71</td>
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<td>tGARCH</td>
<td>2.10</td>
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<td>EVT</td>
<td>13.90</td>
<td>24.41</td>
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<tr>
<td>Model risk</td>
<td>8.85</td>
<td>13.43</td>
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The same actual price series
How frequently do the Swiss appreciate by 15.5%?
measured in once every $X$ years

Model frequency
How frequently do the Swiss appreciate by 15.5%?

measured in once every $X$ years

<table>
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Even more interesting after the event
Even more interesting after the event

Jan 01 Jan 15 Feb 01 Feb 15

HS EVT

−15% −10% −5% 0%
Even more interesting after the event
Even more interesting after the event
Even more interesting after the event
But is the event all that extraordinary?

just eyeballing it seems not that much
Could we do better?

- If one considers who owns the Swiss National Bank
- And some factors, perhaps
  - Money supply
  - Reserves
  - Government bonds outstanding
  - SNB dividend payments
- Yes, we can do much much better than the models used here
- But they are what is prescribed
“Model Risk of Risk Models”
(2014)
with Kevin James (PCA),
Marcela Valenzuela (University of Chile)
Ilknur Zer (Federal Reserve)
Model risk of risk forecast models

Every model is wrong — Some models are useful

The risk of loss, or other undesirable outcomes like financial crises arising from using risk models to make financial decisions

- Infinite number of candidate models
- Infinite number of different risk forecasts for the same event
- Infinite number of different decisions, many ex ante equally plausible
- Hard to discriminate
Do we care?

- Much *anecdotal grumbling*
- The common wisdom maintains that models failed to cover themselves in glory before 2007
- The models today are not much different from the models then
- *So*
- Why are they becoming more and more common
- Why is there so little scrutiny of them (beyond grumbling and tick the box exercises)?
Case study

Model Risk

Myth and reality

Nature of risk

Conclusion
Risk ratios

our proposed model risk methodology

- Consider the problem of forecasting risk for day \( t + 1 \) using information available on day \( t \)
- Supposed we have \( N \) candidate models to forecast the risk, each providing different forecasts

\[
\left\{ \text{Risk}_n^{t+1} \right\}_{n=1}^N
\]

- We then define model risk as the ratio the highest to the lowest risk forecasts

\[
\text{Risk Ratios}_{t+1} = RR_{t+1} = \frac{\max \left\{ \text{Risk}_n^{t+1} \right\}_{n=1}^N}{\min \left\{ \text{Risk}_n^{t+1} \right\}_{n=1}^N}
\]
Model choice

“reputable” models that generally are accepted by the authorities and industry

- **MA** moving average
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- All models re–estimated every day

We can, and have, tried the new shiny. Each new model will increase the *RR*
Risk measures and Data

- Current Basel: VaR 99%
- Proposed Basel III: ES 97.5%, overlapping estimation windows
- Large financials traded on the NYSE, AMEX, and NASDAQ
  - Banking, insurance, real estate, and trading sectors
- January 1970 to December 2012.
- Sampling frequencies daily
- Sample size shown here 1,000 days
Sample results

JPM January 3, 2007, $100 portfolio

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<thead>
<tr>
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<tr>
<td>HS</td>
<td>$ 3.22</td>
</tr>
<tr>
<td>MA</td>
<td>$ 2.91</td>
</tr>
<tr>
<td>EWMA</td>
<td>$ 1.96</td>
</tr>
<tr>
<td>GARCH</td>
<td>$ 2.13</td>
</tr>
<tr>
<td>tGARCH</td>
<td>$ 2.74</td>
</tr>
<tr>
<td>EVT</td>
<td>$ 3.22</td>
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<td>Model risk</td>
<td>1.64</td>
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Model risk — Across all assets

Annual maximum

- Mean
- 95% confidence interval

1980 1990 2000 2010
“Why risk is so hard to measure”, 2015
with Chen Zhou, Bank of Netherlands and Erasmus University, 2015
Objective

- What is the relationship between ES and VaR?
  - VaR(99%) and ES(97.5%) because of Basel
- What are the small sample properties of these risk measures?
- What is the implication of using overlapping estimation windows?
- Risk measures compared by Monte Carlo simulations
  - $10^7$ simulations (yes, we need that many)
- And theoretic analysis
- Across sample sizes and tail thicknesses
ES(99%)/VaR(99%)

- Theory
- N = 2 years
- N = 200 days
- N = 50 years
ES(97.5%)/VaR(99%)
Finite sample properties of VaR

\[ \alpha = 3 \]

- true VaR
- VaR estimate
- 99% confidence interval

years

2

5

10

15

20

VaR
Finite sample properties of VaR

\( N = 1000 \)
Finite sample properties of VaR

\( N = 300 \)
Is ES really better than VaR?

yes, I know it is subadditive

- VaR is also subadditive unless tails are *superfat*
  - (tail index $< 2$)
- In practice, ES is VaR times a constant
  - Affected by tail thickness and sample size
- ES is less precisely estimated than VaR
- With the distributions and probabilities considered here, VaR is preferred to ES
Estimation with overlapping data

- 10 and 50 day windows
- Also t–GARCH and CRSP data
- Compare ($N$ sample size, $H$ overlap interval)
  1. $H + N$–day overlapping estimation
  2. $H \times N$ day non–overlapping
  3. $N$ days with $\sqrt{H}$ scaling
- $\sqrt{H}$ scaling is more robust than estimation with overlapping data
Conclusion

- VaR beats ES
  - Only reason to prefer ES is when concerned with manipulation
- Overlapping estimation cannot be recommended
- Minimum sample size thousand days
Nature of risk
Why models perform the way they perform

1. The statistical theory of the models
2. The nature of risk
Forecasting a tail when we know the distribution

- Asymptotically everything might be fine but what are the small sample properties?
- With a properly specified model, a 99% confidence interval may be (VaR=1)
  - 500 observations
    \[ \text{VaR} = \text{runif()} \]
  - 1,000 observations,
    \[ \text{VaR} \in [0.7, 1.6] \]
  - 10,000 observations
    \[ \text{VaR} \in [0.9, 1.13] \]
And in the real world

- Where returns follow an unknown stochastic process
- The uncertainty about the risk forecasts will be much higher
- This goes a long way to explain why different risk models, each plausible, can give such widely differing results
The nature of risk

● We have classified risk as *exogenous* or *endogenous*

*exogenous* Shocks to the financial system arrive from outside the system, like with an asteroid

*endogenous* Financial risk is created by the interaction of market participants

“The received wisdom is that risk increases in recessions and falls in booms. In contrast, it may be more helpful to think of risk as increasing during upswings, as financial imbalances build up, and materialising in recessions.”

Andrew Crockett, then head of the BIS, 2000
Risk is endogenous

- Market participants are guided by a myriad of models and rules, many dictate myopia
- Prices are not Markovian

Risk models underestimate risk during calm times and overestimate risk during crisis — they get it wrong in all states of the world
Two faces of risk

- When individuals observe *and* react — affecting their operating environment
- Financial system is not invariant under observation
- We cycle between virtuous and vicious feedbacks
  - risk reported by most risk forecast models — *perceived risk*
  - *actual risk* that is hidden but ever present
Endogenous bubble

Prices
Endogenous bubble

- Prices
- Perceived risk
The lessons are...

- Risk is created out of sight in a way that is not detectable
- Attempts to measure risk — especially extreme risk — are likely to fail
  - systemic risk measures like CoVaR, SES/MES, Sharpley, SRisk do not remotely capture systemic risk
  - every systemic risk estimation method that is based on market data is likely to fail
- Why?
  - endogenous risk
  - stability is destabilizing
Conclusion
It matters what models are used for and how they are used

- Risk models are
  - most useful for risk controlling traders
  - less useful in risk capital allocation
  - mostly useless for financial regulations
  - dangerous when used for macro-prudential policy

one better not fall into the trap of doing probability shifting
Harmonization

- If we regulate by models we must believe there is one true model
- Therefore, banks should not report different risk readings for the same portfolio
- However, forcing model harmonization across banks is pro–cyclical
- And forcing the same models to be used for everything internally is also pro–cyclical
- And pro–cyclicality negatively affects economic growth and increases financial instability

model harmonization cannot be recommended for macro–prudential reasons
So

- Risk models are subject to considerable model risk, but the signal is often useful.
- If one understands the model risk of risk models, they can provide a useful guidance.
- Concern that important policy decisions are based on such poor numbers.
- Basic compliance suggests that risk models outcomes should contain *confidence bounds*.
The cost of a type I or type II error is significant.

The minimum acceptable criteria for a risk model should not be to weakly beat noise.
Why do CCP’s play such a small role in the U.S. repo market and why that might change?

Antoine Martin
Federal Reserve Bank of New York

The views expressed in this presentation are my own and may not reflect the views of the Federal Reserve Bank of New York or the Federal Reserve System.
Agenda

- Overview of the US Repo Market
- Why do CCP’s play such a small role in the U.S. repo market?
  - Main economic functions of CCPs
- Why that might change?
  - Unintended effects of regulatory reform on the repo market
  - Balance sheet netting without exposure netting
Overview of the U.S. repo market
What is a repo?

- A repo is the sale of a security, coupled with the promise to repurchase the security at a specific future date.

1. Collateral provider sells $100 of securities for $95 in cash.

2. Next day, collateral provider pays $95, plus “interest”, in cash to repurchase the securities.
What is a tri-party repo?

In a tri-party repo, a third party called the clearing bank provides clearing, settlement, and financing services.

Clearing Bank balance sheet

1. Collateral provider sells $100 of securities for $95 in cash.

2. Next day, collateral provider pays $95, plus interest, in cash to repurchase the securities.
Europe vs. U.S. repo markets

- In Europe, the repo market is mainly interbank
  - Market participants are more homogeneous and tend to trade on both sides of the market
  - CCPs play an important role
  - Substitution between secured (repo) and unsecured interbank market

- In the U.S., the repo market is a key funding market for securities dealers (non-banks)
  - Market participants are heterogeneous and tend to trade on one side of the market.
  - Dealers fund their inventories
  - They also intermediate between their clients and cash investors—Matched books
Segments of the U.S. repo market

Bilateral cash
Investors:
• Hedge funds
• Asset managers
• others

$1.22 T

$ 2.07 T

Tri-party cash
Investors:
• MMFs
• Securities lenders
• others

$1.57 T

GCF

$ 0.32 T

Tri-party repo market

Volumes as of February 2015

• PB clients
• Hedge funds
• others

Cash

Securities
Collateral in tri-party repo

Collateral in Triparty

Billions $


Corporates ABS Equity Money Market Munis Other
Priv Lab CMO Whole Loans Agency CMOs Agency MBS Agency Deb US Treasuries
Collateral in bilateral repo

Collateral in Bilateral Repo

$ billions

May 13  Aug 13  Dec 13  May 14  Sep 14  Jan 15

U.S. Treasuries including STRIPS
All other Collateral
Why do CCP’s play such a small role in the U.S. repo market?
Main economic functions of CCPs

- Netting of exposures
- Orderly liquidation
  - Reduces fire-sale risk
- Risk sharing
- Transparency and Reduction in operational risk
Netting exposures with cycles

- Multilateral netting example
- Exposures and collateral needed when no CCP
- No exposures and no collateral needed with CCP
Netting with no cycles

- B does matched book trades
- W/O CCP: B is exposed to C, A exposed to B
- With CCP: Risk is reduced along the chain
  - If CCP is less risky than B
  - The CCP can shorten the length of the chain
- CCP does not reduce collateral needs
Where are repo CCPs most useful?

- Repo CCPs appear to already exist in markets where they are most useful, because there are opportunities for multilateral netting
  - European repo market
  - GCF repo in the U.S.

- One exception: U.S. bilateral interdealer market does not have a CCP
  - Perhaps because of limitations related to the clearing and settlement of specific collateral
Why might CCPs play a larger role in the U.S. repo market?
What has changed?

- New regulation, notably the Supplementary Leverage Ratio (SLR) has been having an important effect on the US repo market.

- The SLR is like a tax on intermediation activity that is proportional to the size of an intermediary’s balance sheet.
What should we expect?

- A tax is expected to discourage activity being taxed
  - We should see a decrease in tri-party repo volumes
  - The effect should be more pronounced for institutions for which SLR is likely to be binding

- The tax is not risk-weighted
  - The impact should be more pronounced for safe than risk assets

- If cost of intermediation has increased, intermediation spreads should increase
Volume in TPR market has decreased

Volumes for Triparty

- Large Dealers
- Medium Dealers
- Small Dealers
- Federal Reserve
Share of large dealers has decreased

Shares for Triparty

- Small Dealers
- Medium Dealers
- Large Dealers
- Federal Reserve

Date:
- Jan 11
- Jan 12
- Jan 13
- Jan 14
- Jan 15

Percent:
- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- 60
- 65
Volume of risk assets has increased

Volumes for Non Fed Eligible Triparty

- Large Dealers
- Medium Dealers
- Small Dealers
Little change in shares of risk assets
Big change in shares of safer assets

Shares for Fed Eligible Triparty

- Small Dealers
- Medium Dealers
- Large Dealers
- Federal Reserve

Date:
- Jan 11
- Jan 12
- Jan 13
- Jan 14
- Jan 15

Percent:
Concentration in the market is down

Concentration in Triparty

HHI Gini Coefficient

Jan 11 Jan 12 Jan 13 Jan 14 Jan 15

HHI Gini Coefficient
Smaller decrease for risk assets

Gini Coefficient in Triparty

Non Fed Eligible
Fed Eligible
Particularly since 2013

HHI in Triparty

Non Fed Eligible
Fed Eligible
Effect on the CGF repo market

- The GCF repo market is the main funding source for some dealers who cannot obtain the funding they want in the TPR market.

- Instead of borrowing directly from TPR cash investors, they borrow from large dealers who borrow from TPR investors (matched-book).
Decline in CGF net lending volume

Daily Net Cash Positions by Dealer Group

Monthly Average

$ billions

Mar 11 Sep 11 Mar 12 Sep 12 Mar 13 Sep 13 Mar 14 Sep 14 Mar 15

Non-BHC Dealers Small BHC dealers Large BHC Dealers
Increase in interest rate spread

Overnight Treasury GC Repo Spread

Overnight Treasury GC Repo Rates

Triparty rate excludes Federal Reserve. Source: DTCC, FRBNY
How to reduce the cost of the SLR?

- Balance sheet netting: Netting of equivalent obligations for the calculation of regulatory capital
  - Obligations must have the same maturity and counterparty
  - In the case of repos, the collateral need not be the same
Example: Proposed expansion of GCF

- The expansion would allow registered investment companies (RICs) to become GCF members.
- This would allow balance sheet netting for dealers that intermediate between RICs and other dealers.
Other proposals

- LCH and CME have made other proposals
- They are thinking about an agent model, similar to CCPs for derivatives
  - Big departure from existing repo clearing arrangements
  - Non-members can clear through agent members
  - Agent members get fees, guarantee client performance
  - CCP does not guarantee performance to client
- This has the potential to include a much wider set of market participants, including borrowers
Proposals could evolve

- Clearing limited to Treasury collateral at first
  - Benefits with respect to fire sale risk small
  - But could be expanded to other collateral classes later

- Repo CCP could attract trade from bilateral repo
  - This sector opaque, CCP could increase transparency
  - It may be possible to have a CCP for the specials market
Potential concern

- Balance-sheet netting without exposure netting
- Suppose A lends $1 to B against Agency MBS.
  - A's balance sheet increases by $1
  - In case of default of B, A will have an exposure secured by the Agency MBS
- Suppose A lends $1 to B against Agency MBS and B lends $1 to A against Treasuries
  - If the two trades have the same maturity, the balance sheet of A has not increased (balance-sheet netting)
  - But if B defaults, A has an exposure that is secured by Agency MBS.
B.S. netting without exposure netting

- In both examples, A's exposure to B's default is essentially the same
  - To a first approximation, due to haircuts and perhaps other considerations
- In the first example there is an SLR cost while in the second example there is not
- In the second example, there is balance sheet netting without exposure netting
Example in the case of a CCP

- Without CCP: No balance-sheet netting for B
- With CCP: B can net the exposure with the CCP
- But CCP exposed to failure of B
Potential implementation difficulties

- Big challenge: repo CCP would need to satisfy Cover 1 w.r.t liquidity
  - Repo CCPs need way more liquidity than derivative CCPs: repo settlement is notional amount

- Potential solutions:
  - Obligation from members to provide liquidity
  - “Haircutting the unwind”
  - Committed lines of credit
  - Position limits to reduce liquidity need

- Does the agent clearing model work for repos?
  - Question about agent guarantee in an agent model
Conclusion

- Repo market in the U.S. is not an interbank market
  - Market for funding dealer inventories and the securities of dealers’ clients

- Until recently, there was little interest for a repo CCP in the US—except for interdealer GC market

- SLR has had an impact on the US repo market
  - And has led to a strong interest for a repo CCP

- Liquidity will be major challenge to the creation of a repo CCP