RECENT ADVANCES IN QUANTITATIVE RISK MANAGEMENT
GARP/TONGJI UNIVERSITY, SHANGHAI, JUNE 4 2013
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INTRODUCTION
FINANCIAL ECONOMICS ON RISK MANAGEMENT

- Banking intermediation theory
  - Risk intermediation
  - Liquidity intermediation
  - Information intermediation
- Risk management in value creation
TOTAL RISK MANAGEMENT

Risk identification

Risk Optimization

Risk Measurement

Risk Control

Risk Monitoring

Risk governance
IDENTIFICATION & REPORTING

• Recognition and detection of different risk events that the financial institution is exposed to in the cause of the normal business
• Based on expert judgment, loss experience
• Silo risk analysis

holistic and integrated enterprise approach to risk

• Low frequency and high severity events
• Knowledge as measurement and theory (Diebold et al. 2010)
  • Known
  • Unknown
  • Unknowable
• Quantification of the risk exposures in order to compare such exposures to the institution's defined risk tolerances.
• Expert judgment, model based analysis including various quantitative techniques
• Survival bias, hindsight bias…
MONITORING AND REPORTING

• Ongoing monitoring and reporting of the quantified risk against the established risk tolerance criteria in order to ensure that risks to performance and shareholder value can be properly disclosed to the management and public
• Monitoring and reporting on the data collected from real or projected losses
• Data scarcity, disintegration and misleading statistics
MITIGATION AND CONTROL

- Actions taken to keep the actual risk profile at or below the agreed risk tolerance levels.
- Limit system, collateral and other mitigation management, insurance, derivatives
- Financial product innovations
OPTIMIZATION AND BUDGETING

• Optimal decision making on risk appetite, risk based business planning and risk adjusted performance analysis
• Rule or model based approach based on regulatory or economic criteria
• Risk tolerance and allocation
PORTFOLIO RISK

- $S(t) = n \times 1$ vector of risk factors
- $h = m \times 1$ position vector for the m instruments.
- Portfolio value at future time $t$

$$\pi(S(t)) = \sum_{k=1}^{m} h_k p_k(S(t))$$

- What is the distribution of the portfolio value?
RISK MEASURES

Coherent risk measures (Artzner et al., 1999)

- **Subadditivity** --- $m(X+Y) \leq m(X) + m(Y)$
  - Diversification matters
- **Homogeneity** --- $m(tX) = tm(X)$
  - No scaling effect
- **Monotonicity** --- $m(X) \geq m(Y)$ if $X > Y$ a.s.
  - Riskiness is duly reflected
- **Translation invariance** --- $m(X+r) = m(X) + r$
  - Risk free asset doesn’t matter

Other risk measures
Spectral risk measures (Acerbi, 2002) – based on risk aversion functions
Distortion risk measure (Wang, 2002 and Balbás et al., 2008) – convex vs. concave functions

Comparisons and summary: Gzyl and Mayoral, 2006
MARKET RISK CAPITAL REQUIREMENT

• Issues
  • Time scaling
  • Static portfolio
  • Market liquidity

• Basel Committee proposals
  • Incremental Risk Charge (2010)
  • CP on trading book (2012)
    • ES to replace VaR
    • Liquidity horizon (Skoglund and Chen, 2011)
    • Trading with liquidity concern (Skoglund et al. 2011)
TAIL CALIBRATION

• Limited extreme data
• Hard to calibrate the best distribution for the tail
• What do people do?
  • Stress tests
    Used as complementary independent test required by regulators
  • Use consortium data
    Frequency and severity data e.g. operational risk
  • Extreme value theory
  • Extreme theory models and tail index
  • Importance sampling
    Importance kernel
EXTREME EVENTS
AND INTEGRATED
STRESS TESTING

• Recent Financial Regulations (since 2011)...
  • Basel III
  • Comprehensive Capital Adequacy Review (CCAR)
  • Solvency II
  • ...

have either included stress testing as a complementary risk analysis or directly employed a stress scenario based approach to measure tail risks and capital charge
INTEGRATING EXTREME EVENTS INTO TAIL RISK CALIBRATION

• Classical risk analysis (VaR)
  • Focused on historical or current market calibration
  • Back tested on historical data
  • Optionally Include Period of Historical Stress in Calibration
    • E.g., Basel III stressed calibration of models

• Stress testing
  • Include Historical Events that are not Part of Calibration Period
    • E.g., 1987 stock market crash
  • Forward Looking, Think Outside the Box…
    • Can use information from sensitivity analysis
      • Most influential risk factors, risky subportfolios
TYPE OF STRESS TESTING

- Market Based Stress
  - Based either on economic conjecture or on historically severe loss events
  - Can be based on reverse impact analysis … what scenarios will cause large losses, and, are they plausible?

- Guard Against Model Specification Risk
  - Model specification, especially model parameters such as volatilities and correlations, are usually shocked
A MODEL FOR INTEGRATED STRESS TESTING

- Markov switching simulation model as basis for an integrated stress testing framework
  - Can support the typical structural break time series model as well as many deviations from a regular model setting
  - Treat stress test essentially as a deviation from the base model i.e., a structural break from the base risk model and its parameters implied from the historical period of model calibration
  - Incorporate forward looking views on events that may not be part of the historical data used in base model calibration
Stress events represent events in the future that typically are not counted for in the historical data. Hence, they are regime shifts or structural breaks in comparison with the base risk model.

- $m$ states

$$X(t) = g_i(X(t)) \text{ if } S = S_i$$
$$p_i = p(S_i)$$
$$\sum_{i=0}^{m} p_i = 1$$

- Functions $g$ for $i=1,\ldots,m$ are stress events and can be degenerated distributions.
MARKOV SWITCHING SIMULATION

• The switching simulation model encompass most of the well known structural break models including …
  • Markov regime switching models by Hamilton (1989),
  • Threshold Autoregressive models by Tong (1983)
  • ..

• It can support the typical structure break time series model as well as many deviations from a regular model setting.
  • This is an important model feature as a stress test is essentially a deviation from the base model i.e., a structural break from the base risk model and its parameters implied from the historical period of model calibration.
MOTIVATION

- Once a rare event has happened ... the impact of that event in the future is to
  - Change the probability of that event being persistent ~ stress is likely followed by stress i.e., stress does not happen and go away it may persist for a long time
  - Possibly have a large impact even if the next event is a regular model event ~ GARCH type ”regular” model where the impact of stress is exponentially decaying
A MODEL FOR INTEGRATED STRESS TESTING

- A simple example – embedding rare events in a risk model

This is the "regular" simulation model

The unconditional probability of being in the "regular" simulation model

Once an event (S1 or S2) has happened the conditional probability is used to determine the probability of staying in the rare event
TAIL DEPENDENCY – RISK AGGREGATION

- Portfolio (Enterprise) Risk Management
- Securitization
- …
VARIANCES AND CORRELATIONS

• Most widely used measures of risk and dependency
• Capital Asset Pricing Model (CAPM) and Arbitrage Pricing Theory (APT)
• Linear regression
• Traditional time series models (autocorrelation function based)
RISK AGGREGATION
– TOP-DOWN APPROACH

Enterprise Risk Analysis and Management

Aggregation Technique

Copula is a very popular tool

Pros:
Can be from different system – low implementation cost

Cons:
• Local view
• “Tricky” aggregation technique
LINEAR CORRELATION DEFICIENCIES

- Misinterpretations of correlation
  - The marginals and the correlation determines the distribution
    - only true if we consider elliptic distributions
  - Correlation=0 implies independence
    - only true for the multinormal distribution
    - $X_1=X$, $X_2=X \cdot X$, $X \sim N(0,1)$. $\text{Cov}(X_1, X_2)=0$.
  - Value at risk for the portfolio $X_1+X_2$ is maximal when the correlation $\rho(X_1, X_2)$ is maximal.

- Not invariant under strictly increasing transformations. Linear correlation is not independent of marginal distributions.

$$T : \mathbb{R} \to \mathbb{R}_+, \rho(T(X_1), T(X_2)) \neq \rho(X_1, X_2)$$
CONCEPTUAL ADVANTAGES WITH COPULAS

- Copulas give a better understanding of dependence
- A multivariate model decouples into two parts
  - models for univariate marginals (regardless of moment existence)
  - models for dependence structures
- Copulas give us the opportunity to study the effect of different dependence structures on risk measures for example Value at risk
- The dependence in itself can be studied
A FLEXIBLE COPULA BASED RISK AGGREGATION

- Allow different copula e.g. T, Frank and Clayton for different hierarchy level
- Allow different representations of copulas (empirical and functional)
- Skoglund et al. 2013
Enterprise Risk Analysis and Management

Risk -Based Valuation

Market Risk
Credit Risk
Operational Risk
Other Risk

Risk Drivers e.g. Macro-economic Risk Factors

Pros:
- Integrated view
- Straightforward
- Accuracy

Cons:
- Expensive implementation
  - Time
  - Cost
RISK ATTRIBUTION AND REVERSE STRESS TESTING

• Risk attribution from each risk source
• Non-parametric approach
• Insightful view into risk sources
• Useful for hedging and reverse stress testing

Skoglund and Chen (2009)
Expected Exposure (EE) – Expected future value of positive MtM
Expected Positive Exposure (EPE) – Average of EE
Effective Expected Exposure (eEE) – Non-decreasing EE profile
Effective Expected Positive Exposure (eEPE) – Average of eEE
Peak Exposure (PE) – VaR worst case exposure at certain confidence level

Basel II (2006)
COLLATERAL AGREEMENT (ISDA CSA)

- Legal Agreements to post collateral depending on the MtM of the position, or, netting set
- Key factors:
  - Independent Amount (Initial Margin)
  - Threshold Amount
  - Minimum Transfer Amt
  - Remargin Period

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
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<tbody>
<tr>
<td>Portfolio MTM</td>
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<tr>
<td>Independent Amount (IA)</td>
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<tr>
<td>Threshold</td>
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<tr>
<td>Collateral Held</td>
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<tr>
<td>Minimum Transfer Amount</td>
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<tr>
<td>Rounding</td>
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<tr>
<td>Total Required Collateralisation</td>
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<tr>
<td>Call Appropriate?</td>
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<tr>
<td>Call Amount</td>
<td>9,000000</td>
</tr>
</tbody>
</table>
INCORPORATING WRONG-WAY RISK

APPROACH: MODEL DEPENDENCE BETWEEN DEFAULT AND MARKET

- Need to integrate exposure and default probability path by path (no pre-computation of EE)
- Natural to specify dependence between counterparty credit quality & market variables
- However, requires knowing a lot about your counterparty
- Hull and White, 2011; Skoglund et al. 2013

APPROACH: BUMP UP EE TO TAKE INTO ACCOUNT WRONG-WAY RISK

- Adjust EE to take into account wrong-way risk by multiplication factor
  - Basel II adjusts exposures for default risk regulatory capital with alpha
  - Alpha is floored at 1.2 for internal models or pre-set at 1.4
- Use conservative exposure measure e.g., Peak Exposure
- Basel II; Cepedes et al. 2010
CVA, DVA AND BCVA

1. Recovery rate
2. Exposure time grid
3. Expected Exposure (Institution view or Cpty View)
4. Default probability (Institution or Cpty)
5. Survival probability (Institution or Cpty)

\[
CVA = -(1 - R_c) \times \sum_{n=1}^{N} EE^+(T_n) \times P(T_{n-1} \leq \tau_c < T_n) \times P(\tau_I > T_n)
\]

\[
DVA = -(1 - R_I) \times \sum_{n=1}^{N} EE^-(T_n) \times P(T_{n-1} \leq \tau_I < T_n) \times P(\tau_C > T_n)
\]

\[BCVA = CVA - DVA = \text{fair net price for cpty credit risk}\]

Trade Value = Fair Market Value + BCVA
SAMPLE TRADE

Moving from loss reserve to market price – Analogy: risk based FTP

Old World

Client → Bank Swap Desk
6 month libor

172.4 – 2 bps = 170.4 bps

<table>
<thead>
<tr>
<th>Traders PnL</th>
<th>“Usage”/Re serve Cost</th>
<th>Cost to Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 bps</td>
<td>0</td>
<td>2 bps</td>
</tr>
</tbody>
</table>

New World

Client → Bank Swap Desk
6 month libor

172.4 – 20 bps = 152.4 bps

-20 = -2 -17 +12 -10 -3

Value | Source
-- | --
-2 | Trader PnL
-17 | CVA liability
+12 | DVA asset
-10 | RWA Usage
-3 | FVA liability

<table>
<thead>
<tr>
<th>Traders PnL</th>
<th>“Usage”/Re serve Cost</th>
<th>Cost to Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 bps</td>
<td>18bps</td>
<td>20 bps</td>
</tr>
</tbody>
</table>

Credit protection

Street facing hedges

Moving from loss reserve to market price – Analogy: risk based FTP

15 bp one time fee

3 bp one time fee

hedges
SIMULATING EXPOSURES

Bootstrap counterparty & institution default probability

Obtain hazard rates for cpty and institution, hence cumulative default rates

Price instruments

Adjust exposure and negative exposure for position CSA

Aggregate exposure and negative exposure to netting set

Adjust netted exposure and negative exposure by CSA (netset)

Obtain collateralized exposure and negative exposure as well as exposure measures e.g., EE, NEE, Peak Exposure

Calculate counterparty and institution default probability

Aggregate def. prob, exposures over time and discount

Obtain CVA, DVA and Bilateral CVA
\[ CVA = -(1 - R_c) \sum_{t=1}^{T} EE(T_t)P(T_{t-1} \leq \tau_c < T_t) \]

- Discounted expected exposure (EE)
- Default probability of counterparty implied from e.g., CDS
- LGD on counterparty OTC claims
- Post-process multiplications

From exposure system
From credit system
CAN USE SIMPLE – INDEPENDENT – CVA FOR PRICING

\[
CVA = -(1 - R_c) \sum_{\{t=1\}}^{T} EE(T_t) P(T_{t-1} \leq \tau_c < T_t)
\]

\[CVA_{WR} = CVA \times \alpha\]

Note:
1) Implied alpha should really be computed on portfolio (cpty) basis with all the deals. This will take into account netting benefits.
2) However, when portfolio composition, or market, change implied alpha needs to be updated
WRONG-WAY RISK DEPENDENCE CAN BE SUBTLE AND NOT CAPTURED BY TRADITIONAL CORRELATION MODELS

• Airline example from Gregory (2011)

Oil price high, high exposure, airline jumps to default in severe economic recession (oil price low) with significant decline in travel.

Requires model that capture broad correlations as well as 'corner case' jumps.
### Modeling Cash Flows

#### Cash Inflows
- 100% of retail contractual inflows from performing assets
- 0% cash flows from reverse repos and 100% cash flows from reverse repos of illiquid securities
- 0% cash inflow from committed lines of credit
- 100% contractual inflows from derivatives
- 100% of wholesale contractual inflows from fully performing assets

#### Cash Outflows
- Retail deposit run-off at a minimum of 7.5% or 15%
- Unsecured wholesale deposit run-off by small business at a minimum of 7.5% or 15%
- Unsecured wholesale funding run-off provided by other legal entity customers at 100%
- Unsecured wholesale funding run-off by non-financial corporates at 75%
- Unsecured wholesale funding run-off by non-financial customers, sovereigns, banks and Pias at a minimum of 25%

#### Additional Components of Cash Outflows
- Increased liquidity needs due to valuation changes on derivative transactions
- Increased liquidity needs related to downgrade triggers
- Increases liquidity needs related to potential for valuation changes on collateral posted for securing derivative transactions 20%
- Loss of funding on asset-backed securities, covered bonds and other structured finance products
- Draws on committed credit and liquidity lines and other contingent funding liabilities

#### CBC
- Cash
- Central bank reserves
- Government debt
- Sovereign securities with 0% risk weight
- Corporate bonds (haircuts)

#### Net Funding Requirements
MODELING CASH FLOWS

- Behavioral Modeling of banking business Cash Flows
  - Lending:
    i. decreasing prepayment rates
    ii. Increased default rates
    iii. Increase in loan stock (forward starting)
    iv. Facility drawdowns
  - Deposits:
    i. Increased withdrawal of funds (run-off)
- Business growth (both asset and liability) including roll-over and reinvestment
- Behavioral Modeling of Market Funding Sources
  - Unsecured funding:
    i. committed lines of credit not available
    ii. Wholesale funding rolled over with reduced term and only with counterparties that have a strong relation with the bank
  - Difficulty maintaining secured funding.
    i. Repos are rolled over only if counterparty has strong relation with bank
- Modeling of Derivatives Margin Requirements
  - Increased margin requirements for OTC derivatives (adverse market scenario)
  - Increased collateral posting due to reduced value of collateral (adverse market scenario)
  - Increased margin requirements due to downgrade i.e., rating triggers (bank-specific)
A NEW REGULATION

Regulatory Reporting Standards
- Liquidity Coverage Ratio (LCR)
- Net Stable Funding Ratio (NSFR)

Monitoring Standards
- Contractual Maturity Mismatch
- Funding Concentration
- Unencumbered Assets
- Market Monitoring

Guiding Principles

Minimum Reporting

Guiding Principles

A New Regulation for Liquidity Risk
Pricing Liquidity

Liquidity is a scarce resource and liquidity pricing should be instituted in a way that rewards providers of liquidity and penalize its users.

Assets and Liabilities

- **Term Liquidity Charge**
  - Credit providers of long-term funds with term funding spread
  - Charge long-term illiquid loans with term funding spread
  - Used in bank’s FTP system to provide incentives to branches

- **Contingency Liquidity Charge**
  - Charge opportunity cost of stand-by unsecured funded liquidity reserves
  - Risk premium for offering contingency liquidity at some pre-defined rate

Unencumbered assets

- **Market Liquidity Charge**
  - Term liquidity charge
  - Liquefiability / repoability credit

Accounting for liquidity explicitly in MtM promotes assets that have short-term liquidity – by maturity or liquefiability

Neu et al. 2007.
Skoglund, 2010.
RISK BASED DECISION MAKING
• **Principle 3** Accuracy and Integrity – A bank should be able to generate accurate and reliable risk data to meet normal and stress/crisis reporting accuracy requirements. Data should be aggregated on a largely automated basis so as to minimize the probability of errors.

• **Principle 4** Completeness – A bank should be able to capture and aggregate all material risk data across the banking group. Data should be available by business line, legal entity, asset type, industry, region and other groupings, as relevant for the risk in question, that permit identifying and reporting risk exposures, concentrations and emerging risks.

• **Principle 5** Timeliness – A bank should be able to generate aggregate and up-to-date risk data in a timely manner while also meeting the principles relating to accuracy and integrity, completeness and adaptability. The precise timing will depend upon the nature and potential volatility of the risk being measured as well as its criticality to the overall risk profile of the bank. The precise timing will also depend on the bank-specific frequency requirements for risk management reporting, under both normal and stress/crisis situations, set based on the characteristics and overall risk profile of the bank.

• **Principle 6** Adaptability – A bank should be able to generate aggregate risk data to meet a broad range of on-demand, ad hoc risk management reporting requests, including requests during stress/crisis situations, requests due to changing internal needs and requests to meet supervisory queries.
CAPITAL ALLOCATION

- Capital Allocation is an *ex post* event i.e. attribute capital to business units, risk types, portfolios, sub-portfolios etc.
  - Absolute Risk Contribution (ARC) is an ex post allocation of risk
  - It should add up arithmetically to obtain overall portfolio or bank level risks
  - ARC is an input to risk adjusted performance
  - Capital allocated using ARC is often called as ‘Marginal Capital’
- Different methods for capital allocation are as follows:
  - Variance Covariance based method (incoherent measure of risk: non-monotonous)
  - VaR based method (incoherent measure of risk: subadditive only for elliptical distributions -> far stretched assumption for banks/insurance)
  - Conditional VaR (ES or TCE) (coherent measure)
  - Entropy based risk measures (convex but not coherent measure)
MARGINAL CONTRIBUTION USING EULER’S ALLOCATION

• Applicable for risk measures that are positive homogeneous of degree one of portfolio weights and coherent risk measures
• For such risk measures, RAROC compatible definition of contributions follows so called Euler decomposition
• Marginal contribution application: Add exposure to portfolio if new RAROC is greater
OPTIMIZED RISK ADJUSTED PERFORMANCE

- Portfolio optimization (return and risk of the portfolio)
- Cash flow optimization (asset and liability management)
- Liquidity optimization (liquidity management)
- Credit risk mitigation allocation (credit risk management)
MEAN-ES, MEAN-VAR OPTIMIZATION AND BEYOND

Rockafellar and Uryasev (2000)

- Minimizing ES or VaR with targeted mean return
  - Decision variables are the weights on the assets in the portfolio
  - With additional business constraints

- Solution:
  - For ES: Scenario-based approach converts this stochastic optimization to a deterministic optimization with simulated scenarios
  - For VaR: Iterated Mean-ES
  - For any distortion measures: Distortion measures all satisfy convexity
CASH FLOW MATCH OPTIMIZATION

Chen, 2009

• Asset Liability Management
  • Minimize asset liability cash flow gaps
  • Decision variables are the number of shares of the adjustable positions in the portfolio
  • With additional business constraints

• Solution:
  • Scenario-based approach
  • One-period objective for now
  • Objective function depends on the match decision function
REPLICATING PORTFOLIO AND HEDGING

Chen and Skoglund, 2012a

• Use traded assets to price the target items that do not have a direct market value
• The traded assets must be chosen to capture the characteristics of the target items
• A special case of asset liability match optimization
  • Decision variables are the shares on the traded assets
• Different mismatch criteria, as long as mismatch function are coherent.
LIQUIDITY HEDGING

Chen and Skoglund, 2012b

One of the most challenging aspects of the new regulation is that banks now need to continuously manage a dedicated liquidity portfolio and that the adequacy of this portfolio in hedging liquidity outflows needs to be frequently tested.

- Two general approaches to liquidity hedging in banking industry
  - Acquiring more assets that can generate future cash flows that can complement the potential net cash outflows (hedging with contractual cash flows, structural liquidity mismatch)
  - Dynamic counterbalancing capacity through use of asset sales and repo agreements to generate liquidity at the exact time when net contractual cash flows cannot balance by itself (Basel III liquidity (CBC) portfolio)
HEDGING WITH COUNTER-BALANCING CAPACITY

• Choose initial endowment portfolio: $\alpha$
  which is subsequently traded at $t=1,\ldots,T$ – at minimal total cost
  controlling the (tail) liquidity flow at each time $t$:
Available short-term liquidity

- Cash
- Contingent Credit Line
- Interbank Borrowing
- Assets
  - Regulatory level 1 assets have a zero haircut and include e.g., cash, central bank reserves and premium government and municipal bonds.
  - Regulatory level 2 assets have a regulatory haircut of 15% and include e.g., high quality corporate and covered bonds.
- Short term collateralized loans (repo)
MANAGEMENT OF OPTIMAL LIQUIDITY PORTFOLIO

1. Is the Endowment CBC Portfolio Sufficient?
Manage CBC portfolio, $\alpha$, such that liquidity risk is controlled at each $t$ with limit $\sigma_t$

2. Given Sufficient Endowment Portfolio analyze the Best (Minimal Cost) Execution Strategy for Plausible Scenarios

<table>
<thead>
<tr>
<th>Asset</th>
<th>Optimal (minimum cost) trading strategy for scenario $\omega$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t=1$</td>
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<tr>
<td>Credit facility</td>
<td>10,000</td>
</tr>
<tr>
<td>Bond</td>
<td>-200</td>
</tr>
</tbody>
</table>
LIQUIDITY OPTIMIZATION

- An extension to the last model
- Maximize profit/net income
- Subject to liquidity hedged over the planning period
BEST LIQUIDITY EXECUTION STRATEGY

Chen et al., 2013 (forthcoming)

- All available assets are eligible for execution (fire sale)
- Liquidity evolves in worsening stages and the stage gap needs to be fulfilled
- Assume the assets have
  - Globally available liquidity amounts and a daily market depth
  - Available amounts at first-tier market depth (with a lower execution cost)
  - and, available amounts at second-tier market depth (with a higher execution cost)
- ....Sample Case
  - 2 stages with duration 3 and 2 days
  - Gap that needs to be closed in both stages are 2,000,000 units of CCY
BEST LIQUIDITY EXECUTION STRATEGY

- Optimal to rank liquidity facilities based on their anticipated execution costs and haircuts across the expected stages of a liquidity crisis - execute least quality assets first, saving the liquid assets for later execution as they do not have a significant decrease in value as liquidity distress worsens.
- Refrain from using the least quality assets if they are not needed to keep execution costs to a minimum

<table>
<thead>
<tr>
<th>Liquidity</th>
<th>Available amount</th>
<th>Optimal amount, Stage 1</th>
<th>Optimal amount, Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 2</td>
<td>Day 3</td>
</tr>
<tr>
<td>Cash 1</td>
<td>500,000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cash 2</td>
<td>1,000,000</td>
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<td>0</td>
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<tr>
<td>Bond 1</td>
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<tr>
<td>Bond 2</td>
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<tr>
<td>Equity 1</td>
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<td>200,000</td>
</tr>
<tr>
<td>Equity 2</td>
<td>300,000</td>
<td>0</td>
<td>0</td>
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Raised = 2,000,000

Raised = 2,000,000
BEST LIQUIDITY EXECUTION STRATEGY

• What if even the least quality (value) assets have to be executed to fulfill the gap?
  ➔ Optimal to execute first as their value in the beginning of a crisis is anticipated to be higher than in later more severe stages
  ➔ A firm that underestimates the severity of the liquidity crisis will end up with the least quality assets …. Because, under the firms anticipated stress, it was optimal not to execute those assets to keep execution costs to minimum
OPTIMAL CREDIT RISK MITIGANT ALLOCATION

- Credit risk
- Credit risk mitigation
- Minimizing default loss and/or capital requirement
- Contractual relation between exposures and credit risk mitigant
- Value adjustments on the exposures and credit risk mitigant to reflect effective true value
- Key: multiple exposures vs. multiple mitigations
GENERALIZED MINIMAL COST NETWORK FLOW

- E1, E2, E3 – 3 Exposures
- C1, C2, C3, C4 – 4 Credit Risk Mitigants
- Node “NC” supplies all unsecured portions of the exposures.
- CRM’s act as supply nodes
- Exposure’s act as demand nodes
- The flow costs are the risk weights associated with the mitigates
- The arcs indicate the possible links between mitigates and exposures.
- The flow multiplier are the adjustment to the effective mitigation values
In Basel II Credit Risk Weight Asset Calculation Setting
Chen, 2009

\[ RWA = \sum_{i=1}^{n} \left( \sum_{j=1}^{m_i} SEC_j \cdot RW_{j,i} \cdot M_{j,i} + USEC_i \cdot RW_i \right) \]

- \( n \) – number of exposures
- \( m_i \) - number of credit risk mitigants for exposure \( i \)
RISK ADJUSTED PERFORMANCE MEASURES (RAPM)
TECHNOLOGICAL ADVANCES
HARDWARE

- Memory
- Storage
- Processors
- Communication
SOFTWARE

• Database and reporting
• Large data and data integration
• Grid computing
• In-memory and in-database computing
• Cloud computing
## INTEGRATED RISK MANAGEMENT DASHBOARDS AND REPORTS

### EGRC
- Governance (Internal Audit)
- Risk Management
- Compliance Management

<table>
<thead>
<tr>
<th>MARKET RISK</th>
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<td>Market Portfolio Optimization</td>
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</tbody>
</table>

**Risk Based Limits**

**Stress Testing & Scenario Analysis**

### RISK INFRASTRUCTURE
- Model Validation & Mgmt.
- Risk Engines & High-Performance Risk Analytics
- Pricing Libraries
- Analytical Functions
- Data Quality
- Workflow
- Reporting Mart
- Data Models

### FINANCIAL MANAGEMENT
- ENTERPRISE REPORTING PLATFORM
- OTHER RISK SYSTEMS
- MARKET DATA
SAS IN CHINA

- SAS中国总部
  北京市东城区东长安街1号东方广场E1座1801-1803室

- 上海分公司
  上海市浦东新区陆家嘴环路1233号汇亚大厦15楼

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Thank You!