Challenges in Computational Finance

Drona Kandhai (PhD)
Head of FO Quantitative Analytics – ING Bank
Assistant Professor Computational Finance – UvA CSL

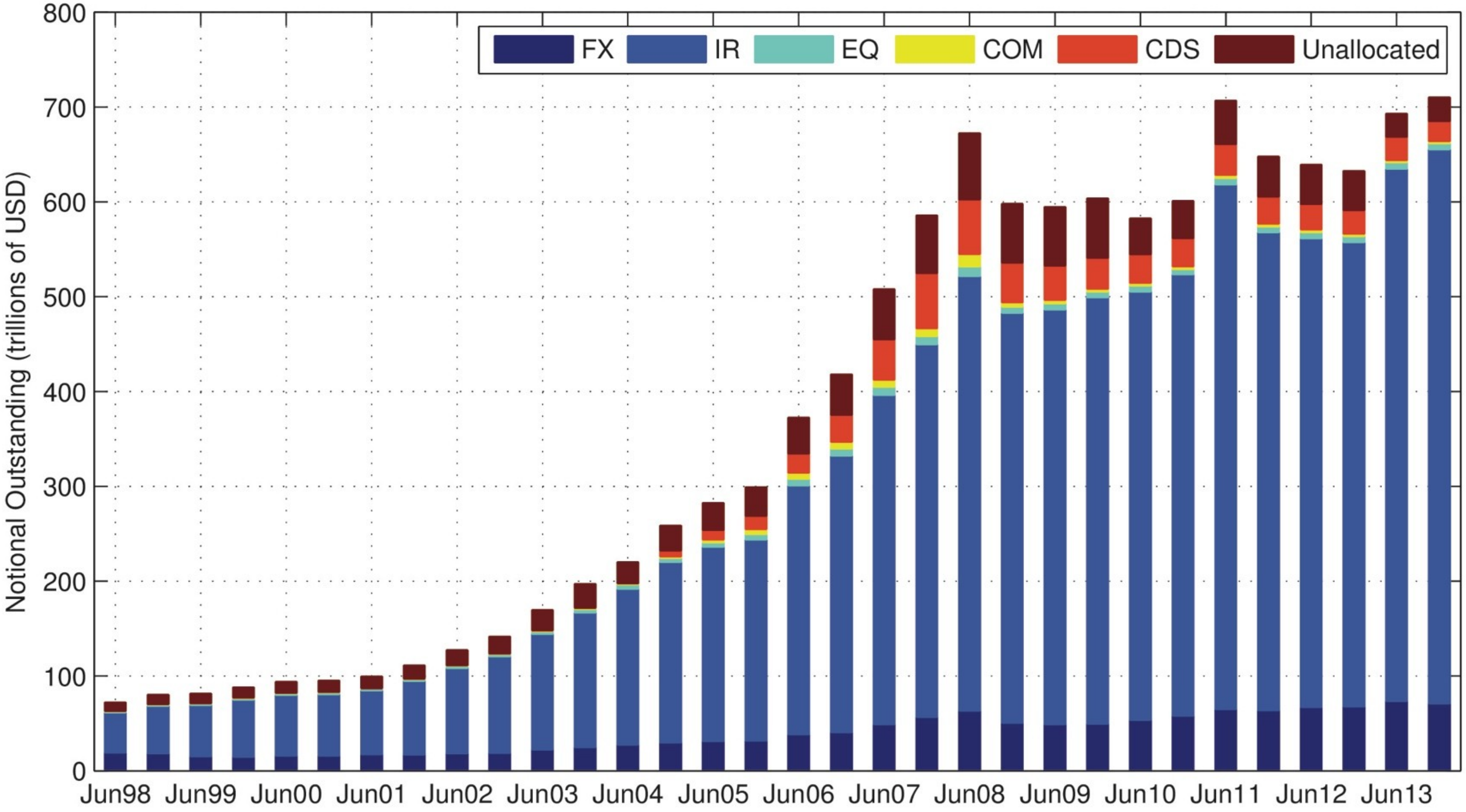
thinkforward

Outline

- Derivatives Valuation and Risk
  - Introduction
  - Challenges after credit and liquidity crisis
  - Beyond the conventional methods
- Final Thoughts
  - Future Quant Profile
  - Teams at ING and UvA

Derivatives
Market Volume in Notional Outstanding

Trillion = 10^12



Loans and Derivatives

- A derivative is a financial product whose value depends on the values of other more basic underlying assets whereas a loan is typically considered to be 'simple' product where you e.g. lend some fixed amount to someone.

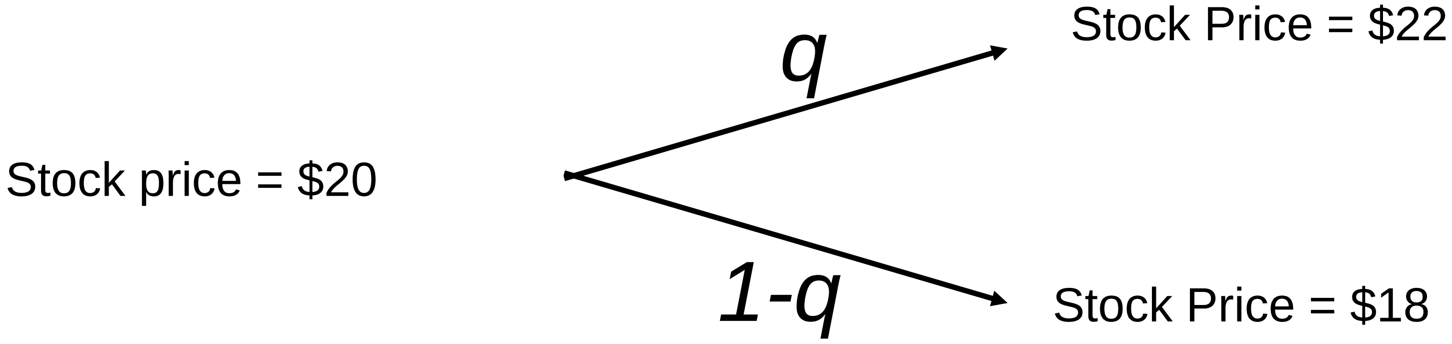
- Key questions:
  - What is the fair premium I should charge?
  - How to manage the risks?

- Before we continue first a 'simple' question:
  - How should we value loans?

ING

My favourite interview question

- **A stock price is currently \$20. Interest rate is 0%.**
- **In three months it will be e.g. either \$22 or \$18.**
- **What is the value of a 'simple' call with strike \$21 and more importantly why is that the fair value?**



Pre-Crisis ’Correct’ Answer

- We can mathematically show that the value is the expectation of the payoff at expiry discounted back to today. The probabilities are implied by the hedging argument

- Generalize by considering many different scenarios for the underlying and take averaged value (Monte Carlo Methods or PDE Solvers)
- Idea has been awarded Nobel price in economics

- Valuation and risk is a trade – risk factor issue!

- Plain-Vanilla is not interesting for quants: It’s all about exotics and smile modelling

Post-Credit Answer …???

- Need to take into account many more aspects:
  - Default of the counterparty
  - All the trades that I have outstanding with the counterparty
  - What about Funding and Liquidity?
  - And Capital?

- Derivatives valuation has become a holistic exercise where even the valuation and risk measurement of a plain vanilla instrument has become a complex issue

- Trade and book level perspective is wrong
  - It is all client level
  - Serious consequences for the organization of Trading and Risk departments

Post-Crisis Complexity
Example of Credit Valuation Adjustment

Credit value adjustment (CVA) is the difference between the risk-free portfolio value and the true portfolio market value that takes into account the possibility of a counterparty's default.

CVA magnitude depends on

- **The probability of default of the counterparty**
- **The possible exposure in the future (only if it is positive!)**

$$CVA = \mathrm{E}\left[1_{\tau \leq T} V(\tau, T)^{+} (1 - \delta)\right]$$

Default — Exposure — Recovery

Portfolio Credit Valuation Adjustment
From Single Instrument to Portfolio

Portfolio of instruments in scope:

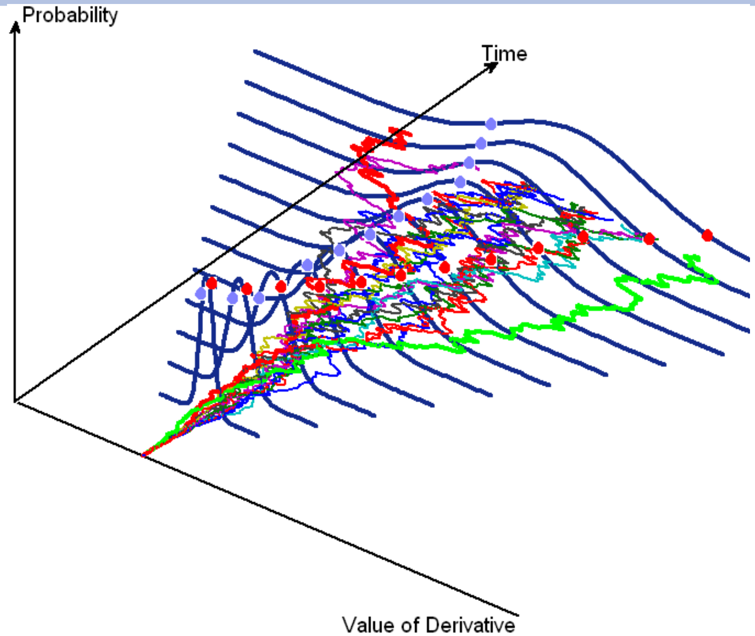
- Roughly 50K instruments exposed to counterparty risk
- All market conventions, netting and collateral rules
- >30 currencies
- >6000 counterparties

Modelling complexity

- Multi-currency Hybrid Modelling (IR/Credit/FX) with Monte Carlo (3K Paths)
- Exposure grid with close to 100 points

IT complexity

- Interfacing with Multiple Systems
- Application Development

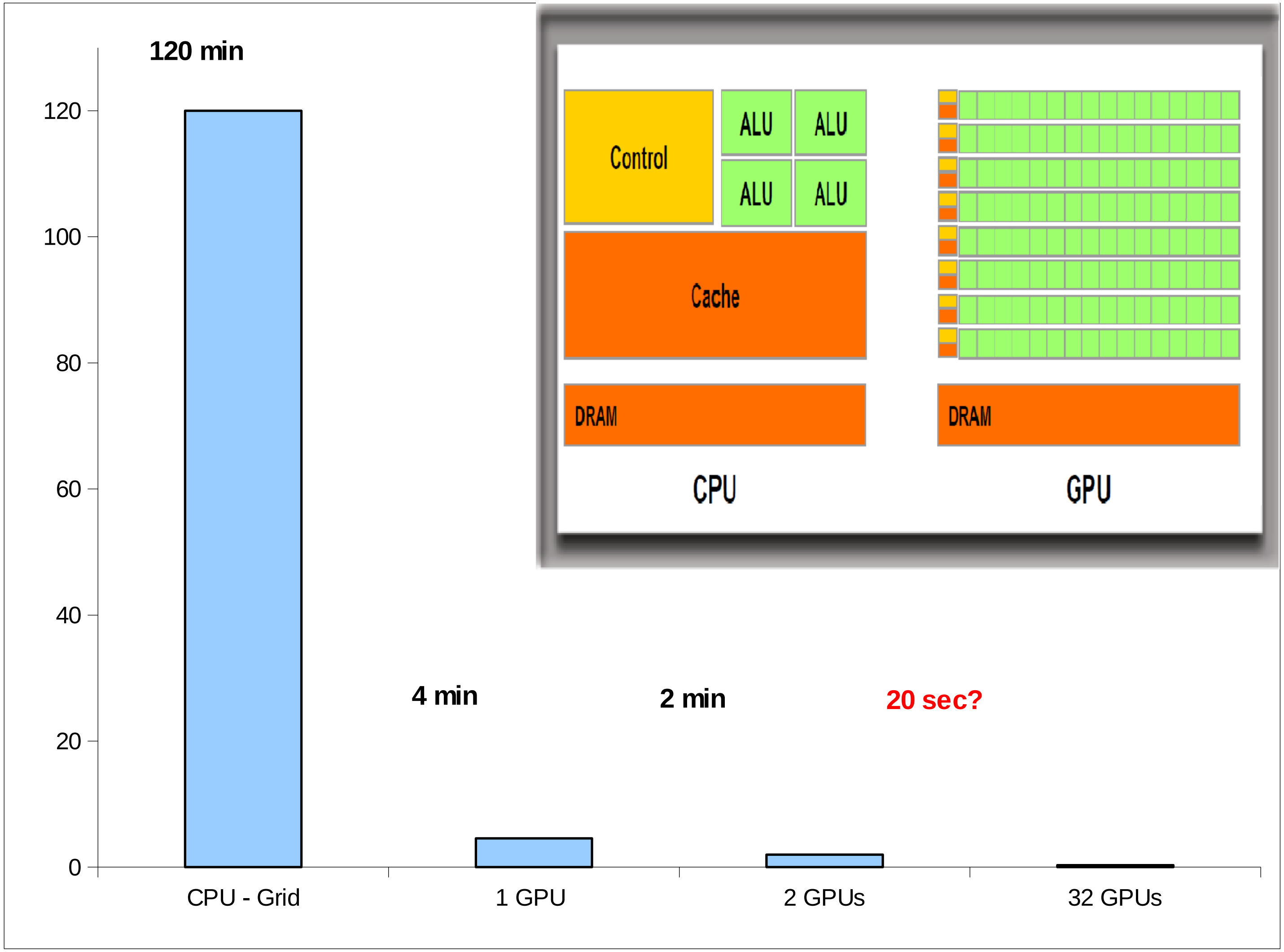


Computational Complexity

- For one CVA run with 50K instruments
  3.75 billion pricing evaluations
- For a full CVA sensitivity run (> 800 runs)

  hundreds of billions of evaluations
- For an HVaR run with 50K instruments
  13 million pricing calls

Computational Challenge
Massively Parallel GPU Computing



Modeling and Numerical Complexity

- Complex Hybrid Modelling (highly mathematical)
  - Large number of correlated market (IR, FX, Inflation and Commodities) and credit risk (CDS) factors in one unified framework
  - Smile in most of the underlying risk factors
  - Wrong-Way-Risk modeling where exposure is correlated with credit
  - Stochastic basis and its correlation with credit
- Numerical Complexity
  - Handling exotic derivatives and capital efficiently is not easy in such a setting
  - Due to large number of sensitivities special numerical algorithms are needed

ING

Beyond CVA: Capital Valuation Adjustment (KVA)

Why do we need KVA?

1. **Capital is set aside as a buffer to absorb unexpected losses.**
2. **Regulators impose Default Capital and CVA Capital.**
3. **These are functions of exposure and therefore market, and hence volatile.**
4. **If we could charge the fee at maturity, ideally one would charge enough to earn return above the hurdle rate on the capital consumed through the lifetime.**
5. **KVA is then the cost of setting up the hedge portfolio to manage the payment of return on capital that will be consumed by the client portfolio through its lifetime.**

ING

Beyond CVA: Counterparty credit risk capital

- **The CCR capital for a horizon of one year is calculated as**

$$K_{t_0}^{CCR} = w\mathrm{EAD}_{t_0},$$

$$\mathrm{EAD}_{t_0} = \alpha \mathrm{EEPE}_{t_0}$$

$$\mathrm{EEPE}_{t_0} = \sum_{t_0}^{1Y} \mathrm{EffectiveEE}_{t_0,t_k} \Delta t_k$$

Non-linearity

$$\mathrm{EffectiveEE}_{t_0,t_k} = \max(\mathrm{EffectiveEE}_{t_0,t_{k-1}}, EE_{t_0,t_k})$$

Inner Simulation

Hybrid Measure

$$EE_{t_0,t_k} = \mathbb{E}^{\mathbb{P}}[V_{t_k}^{+} | \mathcal{F}_{t_0}]$$

- **Needs to extend this along the live of the trade.**
- **On future scenarios, calculating the above capital becomes path-dependent.**
- **Efficient solvers based on Longstaff & Schwartz, SBGM or PDE approaches are needed.**

ING

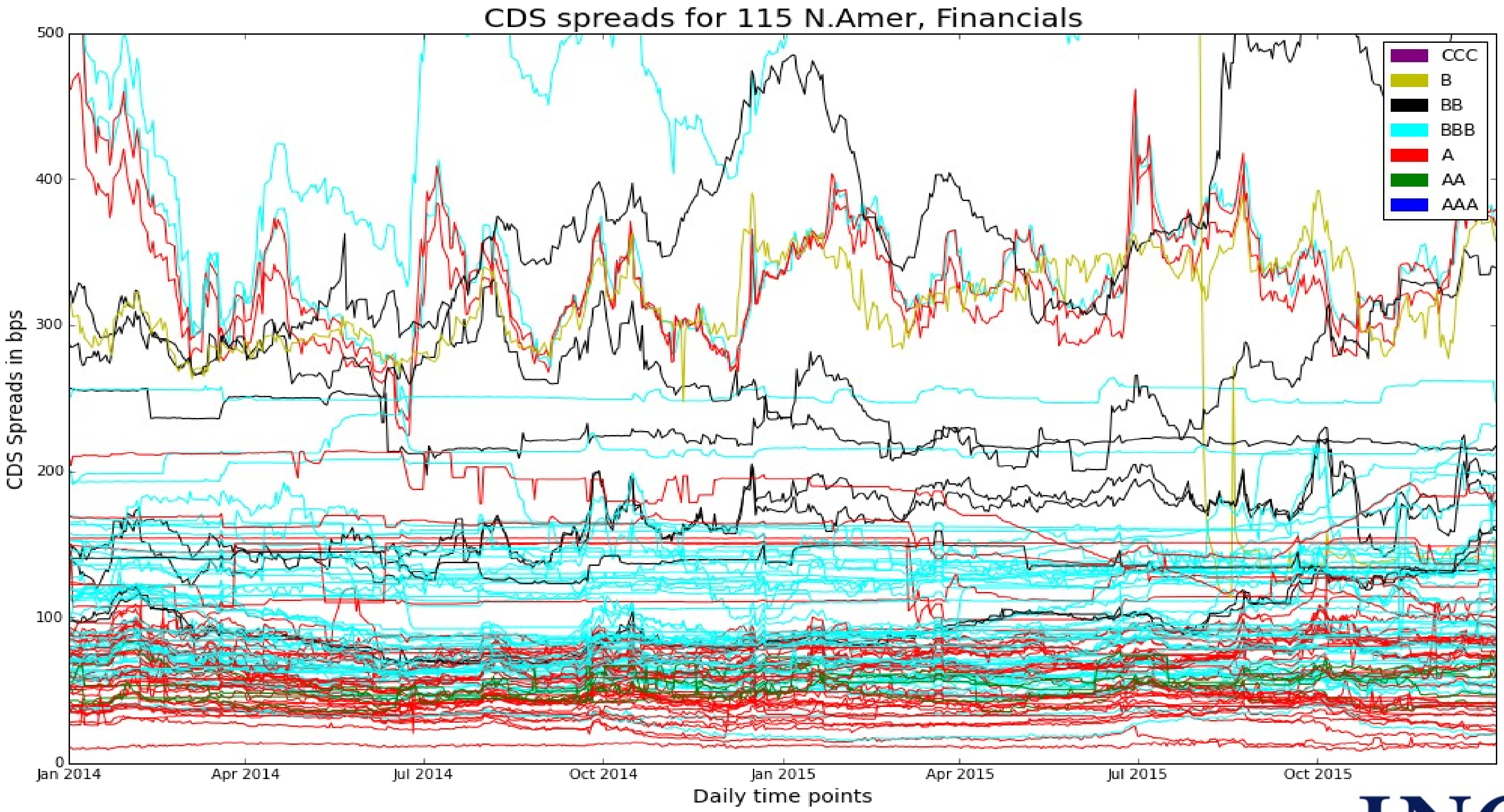
Data Complexity
Proxy CDS Methodology

- **CDS spreads for a large percentage (~ 80%) of institutions are illiquid. So, for CVA calculation for illiquid counterparties, we need a proxy CDS spread.**

- **Regulators have proposed that a proxy curve should be calculated using the following methodology:**
  - **Cluster names with same region, sector and credit rating.**
  - **The proxy spread for a cluster is calculated using mean of liquid spreads in that cluster.**
  - **The illiquid name is then assigned the CDS proxy spread for the cluster to which it belongs.**

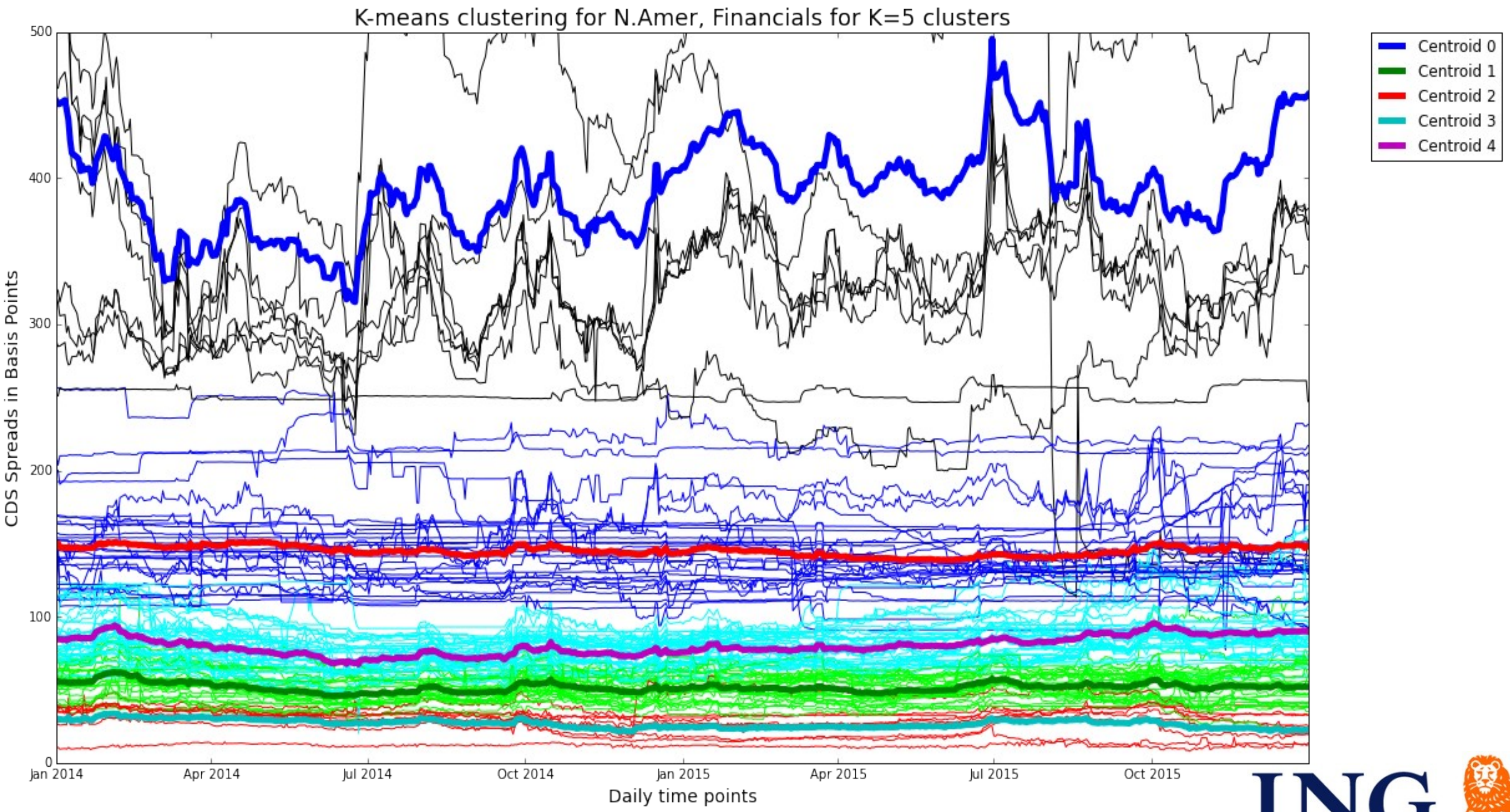
Proxy CDS
Uncertainty of Credit Ratings

- **Credit ratings are unreliable.**



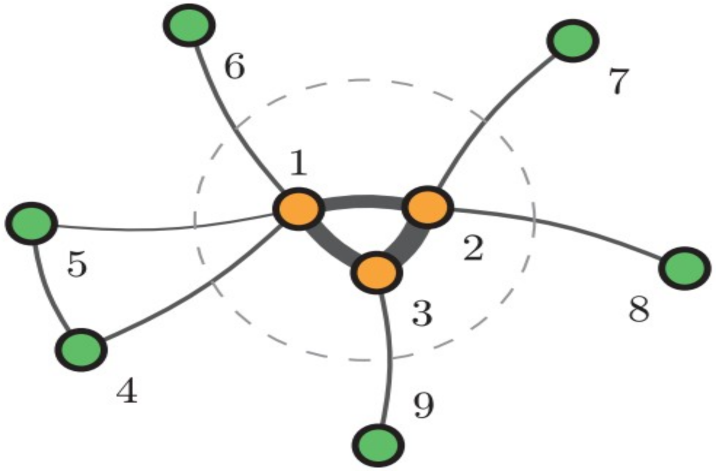
Proxy CDS by Machine Learning Techniques K-means clustering

- **Synthetic rating levels are defined using K-means clustering**



Unconventional Methods
Network models and Systemic Risk

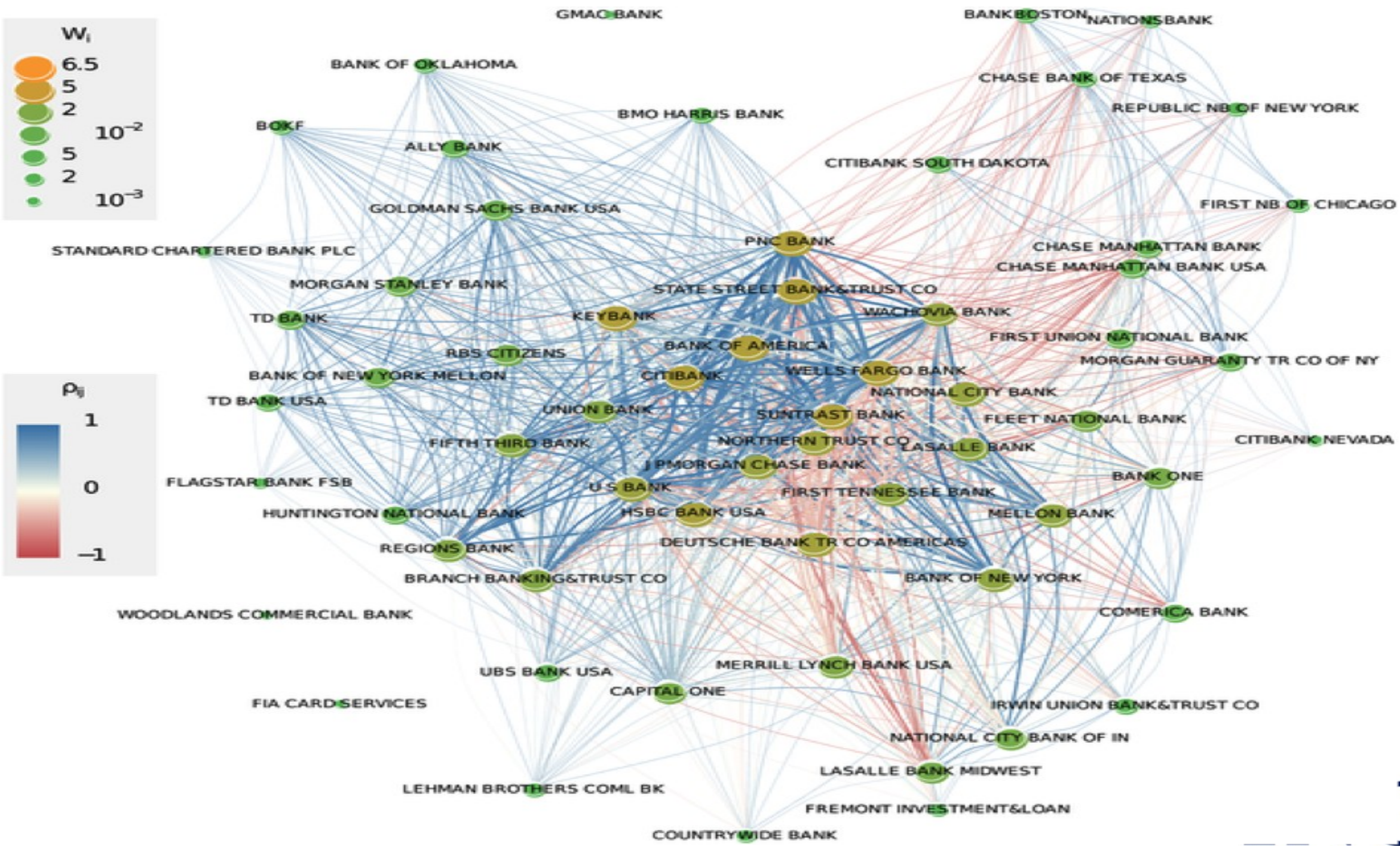
- **Since the financial crisis, ideas from complex systems theory are being increasingly used to measure systemic risk.**
- **In case of OTC derivatives, the contracting parties are exposed to counterparty risk.**
- **Clustering and Cascading in Counterparty Credit Risk.**



Unconventional Methods
Network of counterparty risk

Network based on activity in OTC derivatives

Nanumyan, et al, PLOS ONE, 2015.



Final Thoughts

Pricing of Derivatives versus Loans

Key Open Question in Quantitative Finance:

How to incorporate Cascading Effects and Systemic Risk into our Pricing and Risk Framework?

(Through WWR Modeling and Capital???)

Final Thoughts

- Future is holistic … So is the future Quant Profile!!!!
  - Advanced Analytics:
    - Hybrid Pricing & Risk models even for simple plain vanilla derivatives
    - Data Analytics (client behaviour, market moves and other non-textual data)
    - Complex system based approach for systemic risk

  - High Performance Computing
  - Efficient numerical methods
  - Software Engineering

ING

The Group@ING

The group@ING consists of

- Quantitative Analysts and Developers
- Model Integrators and GUI/DB Developers
- IT Support Engineers (Application and HPC Grid)
- Strong **Joint-Venture** between IT engineers and quantitative analysts

Strong interaction with Business and Risk

- Trading, Sales, Market and Credit Risk

Broad Expertise and Experience

- Financial Markets
- Hybrid Modeling (Interest Rates, FX, Credit, Inflation, Commodities)
- Data Analytics
- High Performance Computing
- Software Development

Research group at UvA

Close collaboration with

- Industry
- CWI and other Academic Partners
- MSc projects (currently 5 are running)
- PhD and other R&D projects
  - UvA/CWI/TU Delft: STW funded project on Advanced CVA Modeling (Kees de Graaf and Qian Feng)
  - ITN Horizon 2020: EU Funded Project Big Data in Finance (Ioannis Anagnostou)
  - ING Funded Post-Doc position on Advanced Modeling (Sumit Sourabh)

Relevant Publications by the Group

- C.S.L. de Graaf, Q. Feng, B.D. Kandhai, and C.W. Oosterlee. Efficient computation of exposure profiles for counterparty credit risk. International Journal of Theoretical and Applied Finance, 17(4):1–24, 2014.
- C.S.L. de Graaf, B.D. Kandhai, and P.M.A. Sloot. Efficient estimation of sensitivities for counterparty credit risk with the finite difference Monte Carlo method. To appear in Journal of Computational Finance, 2016.
- S. Simaitis, C.S.L. de Graaf, N. Hari, and B.D. Kandhai. Smile and default: The role of stochastic volatility and interest rates in counterparty credit risk. To appear in Quantitative Finance, 2016.
- C.S.L. de Graaf, B.D. Kandhai, and C. Reisinger. Efficient CVA computation by risk factor decomposition. In preparation for International Journal of Financial Engineering, 2016
- Q. Feng, et al., Efficient Methods for PFE for Bermudan Swaptions, In preparation.
- S. Sourabh, M. Hofer, B.D. Kandhai, Proxy Tool Revisited. In preparation.