

# Pricing Structured Derivatives

---

Experiences with High-Performance Computing at HVB/Unicredit MIB

---

**Heribert Schütz**

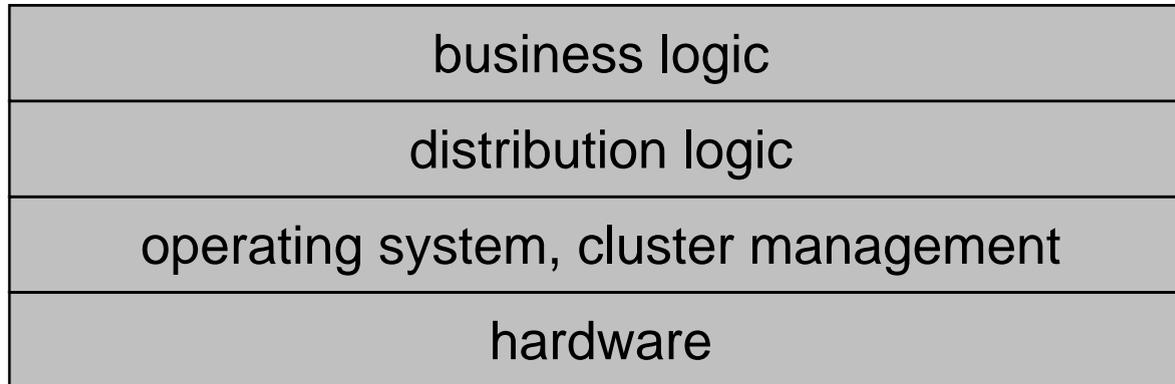
---

Stuttgart, 27 May 2008

# What this talk will be about

---

- Computing prices and sensitivities of structured derivatives
- Parallelization of CPU-intensive Monte-Carlo simulations
- Component stack:



This presentation will concentrate on distribution and business logic.

# Recap: Monte-Carlo Pricing of Structured Derivatives

---

- Structured derivative:
    - A contract about future payments depending on future market prices (of stock, commodities, ...).
    - More complex constructions are possible.
  
  - Monte-Carlo pricing:
    - Randomly generate a high number of possible future market developments.
      - E.g., simulate prices for relevant stock and relevant future dates.
      - The stochastic distribution of the samples must fit with certain model assumptions and market observations.
    - For each generated possible future:
      - Compute the resulting future payments.
      - Discount them to their present value.
      - Add them up (if there are multiple payments).
    - Take the average over all generated futures as an approximation of the "fair price".
-

# Properties of the Monte-Carlo Approach

---

- computationally expensive
  - short simulation steps
  - slow convergence:  $O(1/\sqrt{n})$
  
- still the best solution for many complex derivatives
  
- easy to parallelize  
(see next slide)

# Levels of Parallelization

---

- Parallel pricing of different instruments
    - simple
    - limited granularity
    - sufficient for simple pricing models
  
  - Parallelization of Monte-Carlo simulations
    - necessary for more complex pricing models  
(Monte-Carlo simulations are CPU-intensive!)
    - still relatively simple:
      - Each subjob calculates a subset of the MC samples.
      - Communication happens only at the beginning and the end of a subjob.
      - No synchronization is needed.
      - This allows for flexible job scheduling.
    - sufficient granularity
-

# Speeding Things Up

---

- Hardware
  - more blades
  - newer/better blades
- Software
  - low-level tuning
  - elimination of redundant computations
  - mathematical optimizations

Tradeoff:

- Hardware
    - more plannable (as long as the distribution logic and the network scales)
  - Software
    - cheaper (at least initially)
-

## Speeding Things Up (cont.)

---

- Any speedup will immediately be consumed by more computations:
  - more Monte-Carlo samples for more accurate results,
  - more sensitivities ("Greeks" and risk scenarios),
  - more frequent recomputation of instrument prices,
  - more business.

# Failure Tolerance

---

The reliability of the cluster is ensured on multiple levels:

- Hardware:
    - replicated central components
    - distributed over two locations
    - redundant networks
  
  - System level:
    - heartbeat, automated failover
  
  - Distribution logic  
(see next slide)
  
  - Administration tools:
    - logging
    - system monitoring
-

# Failure Tolerance in the Distribution Logic

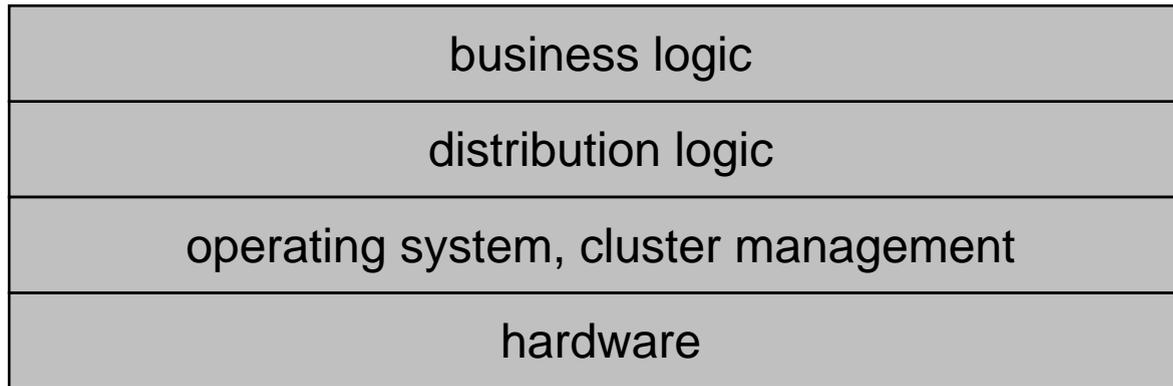
---

- Possible failures:
    - hardware or system level
    - application level (highly volatile code!)
      - crashes
      - runaway computations (e.g., infinite loops)
      - hang-ups (e.g., due to memory exhaustion)
        - Delimit impact to the problematic calculation jobs.
  - Possible reactions:
    - Restart worker process or reboot blades.
    - (Stop and) retry failed (sub)jobs.
    - Give up after a few attempts.
  - Choice of granularity:
    - How frequently do failures occur?
    - How much investment of CPU time are we willing to lose?
    - How expensive are safety measures?
-

# Specialized and Standard Software Components

---

- Component stack:



- Component provenance:

- standard components (commercial or open-source)
- specifically (but externally) developed components
- in-house development

# Specialized and Standard Software Components (cont.)

---

- Further up in the stack, components tend to become more specific.
  - Over time, innovative approaches may become standardized.  
But:
    - Never touch a running system.
    - Do standard components really fit our needs?  
Examples:
      - Flexibility of job submission/scheduling not needed.
      - Job synchronization and communication not needed.
  - Over the lifetime of a component, it moves
    - from fundamental design and implementation
    - towards incremental improvements and tuning.This implies a change in the development model:
    - Initial design requires deeper expertise → external development.
    - Small changes take less overhead when handled in-house.
-

# Heterogeneity

---

- Reasons:
    - to meet different user needs
    - to preserve investments
  
  - Heterogeneous hardware:
    - Intel vs. AMD
    - hyperthreading vs. multi-core processors
    - mixed number of cores per CPU
    - diskless vs. disks
  
  - Heterogeneous software:
    - Linux vs. Windows
    - C++ vs. Java vs. .NET
    - different kinds of financial derivatives
-

# History of Parallelized Pricing at HVB

---

- early 2003:
    - several PCs without a dedicated network
    - instrument-level parallelization only
  - mid 2003:
    - several PCs with a dedicated switch
    - parallelization of Monte-Carlo simulations
  - late 2003:
    - a small blade-based cluster, two-level MC parallelization
  - 2004:
    - a serious blade-based cluster
  - meanwhile:
    - several cluster extensions
    - more functionality, optimizations, improved robustness
    - another cluster with different operating-system, distribution, and application layers
-

# Your contacts

---

## **UniCredit Group**

Markets & Investment Banking  
Bayerische Hypo- und Vereinsbank AG

Didier Vermeiren

Director

Co-Head of Financial Engineering Equities and Hybrids  
Structured Products Development - MMP11

Tel. +49 89 378-13100, Fax +49 89 378-33-13100

[didier.vermeiren@unicreditgroup.de](mailto:didier.vermeiren@unicreditgroup.de)

Dr. Heribert Schütz

Quant-IT Development

Tel. +49 89 378-18620

[heribert.schuetz.extern@unicreditgroup.de](mailto:heribert.schuetz.extern@unicreditgroup.de)

## **Imprint**

UniCredit Markets & Investment Banking

Bayerische Hypo- und Vereinsbank AG

Arabellastr.12

D-81925 München

---

# Disclaimer

The information in this publication is based on carefully selected sources believed to be reliable but we do not make any representation as to its accuracy or completeness. Any opinions herein reflect our judgement at the date hereof and are subject to change without notice. Any investments discussed or recommended in this report may be unsuitable for investors depending on their specific investment objectives and financial position. Any reports provided herein are provided for general information purposes only and cannot substitute the obtaining of independent financial advice. Private investors should obtain the advice of their banker/broker about any investments concerned prior to making them. Nothing in this publication is intended to create contractual obligations on any of the entities composing UniCredit Markets & Investment Banking Division which is composed of (the respective divisions of) Bayerische Hypo- und Vereinsbank AG, Munich, Bank Austria Creditanstalt AG, Vienna, and UniCredit S.p.A., Rome.

Bayerische Hypo- und Vereinsbank AG is regulated by the German Financial Supervisory Authority (BaFin), Bank Austria Creditanstalt AG is regulated by the Austrian Financial Market Authority (FMA) and UniCredit S.p.A. is regulated by both the Banca d'Italia and the Commissione Nazionale per le Società e la Borsa (Consob).

## **Note to UK Residents:**

In the United Kingdom, this publication is being communicated on a confidential basis only to clients of UniCredit Markets & Investment Banking Division (acting through Bayerische Hypo- und Vereinsbank, London Branch ("HVB London") and/or UniCredit CAIB Securities UK Ltd. and/or UniCredit CAIB UK Ltd.) who (i) have professional experience in matters relating to investments being investment professionals as defined in Article 19(5) of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005 ("FPO"); and/or (ii) are falling within Article 49(2) (a) – (d) ("high net worth companies, unincorporated associations etc.") of the FPO (or, to the extent that this publication relates to an unregulated collective scheme, to professional investors as defined in Article 14(5) of the Financial Services and Markets Act 2000 (Promotion of Collective Investment Schemes) (Exemptions) Order 2001 and/or (iii) to whom it may be lawful to communicate it, other than private investors (all such persons being referred to as "Relevant Persons"). This publication is only directed at Relevant Persons and any investment or investment activity to which this publication relates is only available to Relevant Persons or will be engaged in only with Relevant Persons. Solicitations resulting from this publication will only be responded to if the person concerned is a Relevant Person. Other persons should not rely or act upon this publication or any of its contents.

The information provided herein (including any report set out herein) does not constitute a solicitation to buy or an offer to sell any securities. The information in this publication is based on carefully selected sources believed to be reliable but we do not make any representation as to its accuracy or completeness. Any opinions herein reflect our judgement at the date hereof and are subject to change without notice.

We and/or any other entity of the UniCredit Markets & Investment Banking Division may from time to time with respect to securities mentioned in this publication (i) take a long or short position and buy or sell such securities; (ii) act as investment bankers and/or commercial bankers for issuers of such securities; (iii) be represented on the board of any issuers of such securities; (iv) engage in "market making" of such securities; (v) have a consulting relationship with any issuer. Any investments discussed or recommended in any report provided herein may be unsuitable for investors depending on their specific investment objectives and financial position. Any information provided herein is provided for general information purposes only and cannot substitute the obtaining of independent financial advice.

HVB London is regulated by the Financial Services Authority for the conduct of investment business in the UK as well as by BaFin, Germany. UniCredit CAIB Securities UK Ltd., London, and UniCredit CAIB UK Ltd., London, two subsidiaries of Bank Austria Creditanstalt AG, are authorised and regulated by the Financial Services Authority.

Notwithstanding the above, if this publication relates to securities subject to the Prospectus Directive (2005) it is sent to you on the basis that you are a Qualified Investor for the purposes of the directive or any relevant implementing legislation of a European Economic Area ("EEA") Member State which has implemented the Prospectus Directive and it must not be given to any person who is not a Qualified Investor. By being in receipt of this publication you undertake that you will only offer or sell the securities described in this publication in circumstances which do not require the production of a prospectus under Article 3 of the Prospectus Directive or any relevant implementing legislation of an EEA Member State which has implemented the Prospectus Directive.

## **Note to US Residents:**

The information provided herein or contained in any report provided herein is intended solely for institutional clients of UniCredit Markets & Investment Banking Division acting through Bayerische Hypo- und Vereinsbank AG, New York Branch and UniCredit Capital Markets, Inc. (together "HVB") in the United States, and may not be used or relied upon by any other person for any purpose. It does not constitute a solicitation to buy or an offer to sell any securities under the Securities Act of 1933, as amended, or under any other US federal or state securities laws, rules or regulations. Investments in securities discussed herein may be unsuitable for investors, depending on their specific investment objectives, risk tolerance and financial position.

In jurisdictions where HVB is not registered or licensed to trade in securities, commodities or other financial products, any transaction may be effected only in accordance with applicable laws and legislation, which may vary from jurisdiction to jurisdiction and may require that a transaction be made in accordance with applicable exemptions from registration or licensing requirements.

All information contained herein is based on carefully selected sources believed to be reliable, but HVB makes no representations as to its accuracy or completeness. Any opinions contained herein reflect HVB's judgement as of the original date of publication, without regard to the date on which you may receive such information, and are subject to change without notice.

HVB may have issued other reports that are inconsistent with, and reach different conclusions from, the information presented in any report provided herein. Those reports reflect the different assumptions, views and analytical methods of the analysts who prepared them. Past performance should not be taken as an indication or guarantee of further performance, and no representation or warranty, express or implied, is made regarding future performance.

HVB and/or any other entity of UniCredit Markets & Investment Banking Division may from time to time, with respect to any securities discussed herein: (i) take a long or short position and buy or sell such securities; (ii) act as investment and/or commercial bankers for issuers of such securities; (iii) be represented on the board of such issuers; (iv) engage in "market-making" of such securities; and (v) act as a paid consultant or adviser to any issuer.

The information contained in any report provided herein may include forward-looking statements within the meaning of US federal securities laws that are subject to risks and uncertainties. Factors that could cause a company's actual results and financial condition to differ from its expectations include, without limitation: Political uncertainty, changes in economic conditions that adversely affect the level of demand for the company's products or services, changes in foreign exchange markets, changes in international and domestic financial markets, competitive environments and other factors relating to the foregoing. All forward-looking statements contained in this report are qualified in their entirety by this cautionary statement.

## **UniCredit Markets & Investment Banking Division**

Bayerische Hypo- und Vereinsbank AG, Munich; Bank Austria Creditanstalt AG, Vienna and UniCredit S.p.A., Rome  
as of 19 May 2008