



BNP PARIBAS

# CRM for Correlation Trading Books: Modelling and Challenges

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**WBS 6<sup>th</sup> Fixed Income Conference**

24 September 2010

Group Risk Management  
Risk – Capital Markets

# Outline

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- New capital charges: introduction and regulatory overview
- Incremental Risk Capital (IRC) and Comprehensive Risk Measure (CRM)
- Modelling challenges
  - Dependence
  - Observables and inputs
  - Speed and constraints
- CRM model alternatives
  - Fitting tails
  - Parametric fitting
  - Non-parametric analysis
- Joint tail realisations and extreme P&L
- CRM and advanced risk measurement

# Acknowledgements

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We are grateful, for their contribution, help, ideas, comments and fruitful discussions, to our many collaborators at BNP Paribas, and especially to Sascha Wilkens, Jean-Baptiste Brunac, Vera Minina, Teresa Cardoso, Laurent Carlier, Fakher Ben Atig, Tom Hanney

# Overview

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- In the current regulatory climate, CRM is key to maintaining correlation trading as sustainable market activity
- Building a fully consistent CRM-compliant model is a complex task, with many challenges and pitfalls
- Time constraints for implementation, imposed by regulators, dictate pragmatic approach and “cost-benefit” assessment of chosen model and assumptions
- A year since the first consultative papers emerged from the Basel Committee, we still find a wide range of approaches
- Most known model candidates are open to criticism, as there still appears to be more questions than answers in CRM modelling
- In the talk, we discuss some of the challenges and assess different choices, but do not necessarily favour or endorse a particular approach or model

# Trading Book Capital Charge

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## ■ Current formula:

$$\text{Capital} = (m_c + b) \cdot \text{VaR}(\text{GEN}) + \text{VaR}(\text{SPE})$$

- **VaR** is the standard Value-at-Risk measure, based on 99% 10-day loss
- $m_c$  is a model-based multiplier,  $m_c \geq 3$
- $b$  is an additional factor, depending on VaR backtesting excesses,  $0 \leq b \leq 1$
- **GEN** refers to general risk, **SPE** refers to specific risk

## ■ Coming soon

$$\text{Capital} = (m_c + b) \cdot \text{VaR} + (m_c + b) \cdot \text{Stressed VaR} + \text{IRC} + \max\{\text{CRM}, \text{Floor}\} + \text{SC}$$

- **VaR** includes both general and specific risk
- **Stressed VaR** is VaR calibrated to financial crisis data, e.g., 2007-2008;  $m_c \geq 3$
- **IRC** is an incremental charge for default and migration risks
- **CRM** is an incremental charge for correlation trading portfolios
- **Floor** is calculated as  $\alpha$  times capital charge for specific risk according to the modified standardised measurement method for the correlation book (a.k.a “banking-book charge”);  $\alpha = 8\%$
- **SC** is standardised charge on securitization exposures (not covered by CRM)



# IRC and CRM: details

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- Generally penalising for securitisation positions: these are treated with standardised method
- **Incremental Risk Capital (IRC)**
  - Products: flow products – bonds and CDS (if not part of CRM, as defined below); may include listed equities
  - Simulated risks: credit rating migrations and default
- **Comprehensive Risk Measure (CRM)**
  - Although initially considered part of securitisation positions, correlation trading portfolio are “carved out” of standardised charge and subject to CRM and floor
  - Products: correlation instruments and their hedges (*including CDS*), but without “re-securitisation positions” (e.g. CDO<sup>2</sup>) or LSS
  - Simulated risks: Default and migration (as in IRC) and all price risks (multiple defaults, credit spread volatility, volatility of implied correlations, basis risks, recovery rate)
- Risk measure
  - Both are based on 99.9% loss quantile at 1-year capital horizon
  - This contrasts with VaR and stressed VaR, which are much more short-term
  - Rebalancing may be taken into account via shorter liquidity horizons coupled with a “constant level of risk” concept

# IRC and CRM: regulatory text

## ■ IRC

“... is intended to complement additional standards being applied to VaR modelling ... Foremost, the current VaR framework ignores differences in the underlying liquidity of trading book positions. In addition, these VaR calculations are typically based on a 99%/one-day VaR which is scaled up to 10 days. Consequently, the VaR capital charge may not fully reflect large daily losses that occur less frequently ... as well as the potential for large cumulative price movements over ... several weeks or months.”\*

## ■ CRM

“... a bank may incorporate its correlation trading portfolio in an internally developed approach that adequately captures ... all price risks ... in particular ... the following risks ... must be adequately captured:

- the cumulative risk ... from multiple defaults, including ordering of defaults ...
- credit spread risk, including the gamma and cross-gamma effects
- volatility of implied correlations, including the cross effect between spreads and correlations
- basis risk, including both
  - the basis between the spread of an index and those of its constituent single names; and
  - the basis between the implied correlation of an index and that of bespoke portfolios
- recovery rate volatility, as it relates to the propensity for recovery rates to affect tranche prices
- to the extent the comprehensive risk measure incorporates benefits from dynamic hedging, the risk of hedge slippage and the potential costs of rebalancing such hedges.”\*\*

\* bcbs159 - Guidelines for computing capital for incremental risk in the trading book; \*\*bcbs158- Revisions to the Basel II market risk framework

# IRC and CRM: general critique

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- Shortcomings of VaR-based capital charge are recognised, and the requirement that banks increase capital is understandable after the crisis
- At the same time, the approach to incremental capital charges taken by regulators raises questions:
  - Majority of extreme losses suffered by financial institutions were mark-to-market losses and not due to defaults or downgrades
  - Rating migrations have very little to do with trading book losses (rating triggers are extremely rare)
  - Still based on loss quantiles, so inherits all the drawbacks of VaR combined with a higher percentile
  - Model risk increases substantially, yet backtesting for such a high quantile at such a long horizon is likely to be far less accurate, if possible at all
- Specifically for CRM
  - It is not obvious how relevant all risks in the list are to correlation trading
  - Exclusion rules (especially CDO<sup>2</sup> and LSS, but not their hedges) are likely to trigger capital charge driven trading activity, rather than sound risk practices
  - Even though dynamic hedging is mentioned in principle, the constant level of risk concept makes it very unclear how this can be implemented in practice
  - Application of the banking book style floor essentially invalidates the exercise (more later)



# CRM: on the positive side

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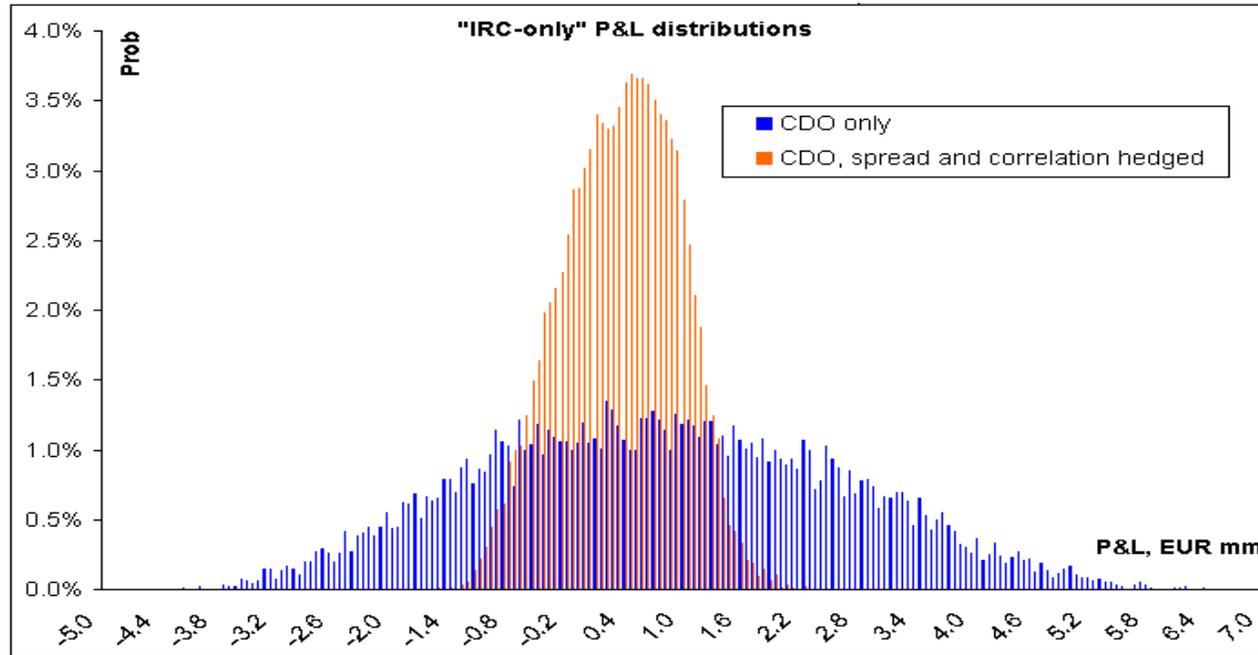
- A comprehensive risk measure is still expected to outperform the alternatives in terms of capturing relevant risks
- Standardised charge is quite punitive for trading:
  - inspired by the banking book
  - based on notionals and PVs, depending on direction (long or short protection)
  - netting rules are extremely restrictive and create perverse incentives for hedging
  - even the floor, which is based on a percentage of standardised charge, is already quite large
  - some generic examples follow later
- IRC falls short for structured credit/correlation trading
  - Model-based approach is preferable, since it naturally takes into account offsetting of similar positions
  - Defaults and severe credit deterioration are likely to be among tail events causing extreme losses
  - However some key risk scenarios will be missed
    - large spread movements in the market preceding rating actions or defaults
    - significant risk redistribution in the tranche/correlation market
    - movement of the index not immediately followed by constituents

# Generic example

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- Take a typical “vanilla” CDO position
  - Buy protection on a mezzanine bespoke tranche
    - 3 - 7%, 5Y maturity, EUR 10mm notional
    - 100-name portfolio, average 5Y CDS spread of 132bp, dispersion, mix of names
  - Spread-hedge with single-name CDS
    - Sell single-name CDS protection on underlying names
    - Leverage is roughly 5.6, so total CDS position has notional of ~ EUR 56mm
  - Correlation-hedge with index tranches
    - Both European and US names in the baskets, so use both iTRAXX and CDX
    - Use Series 9 of both indices, so a maturity mismatch; also note that e.g. 7Y contracts have by now rolled down and have about 5 years remaining
    - Sell protection on iTRAXX-S9 0-3% and 3-6% 7Y, ~ EUR 8.1mm combined
    - Long equity/short mezzanine protection in CDX-S9 0-3% and 3-7% 7Y (~ EUR 4mm net short protection) and 10Y (~EUR 0.4mm net short protection)
  - Delta exchange on correlation hedges
    - Buy iTRAXX-S9 7Y index protection ~ EUR 48mm
    - Net buy CDX-S9 7Y and 10Y index protection, ~ EUR 28mm equivalent

# Generic example: “IRC-only” - not enough



- Take KMV-type correlated asset return model, simulate rating transitions, defaults; revalue position in all scenarios by mapping migrations to spread movements; build a one-year P&L distribution; read 0.1% quantile (IRC equivalent)
  - IRC charge on combined position comes out at EUR 1.2mm
- The following scenarios would produce this or larger loss
  - CDX correlation shift downward by 15-20% + spread widening, defaults: EUR 1.4mm loss
  - CDX basis increase by 13% + iTRAXX correlation shift downward by 10%: EUR 1.2mm loss
- Standardised charge: EUR 69mm, clearly overkill
- Deficiency of IRC is more pronounced on the level of “industrial” correlation book

# Modelling CRM

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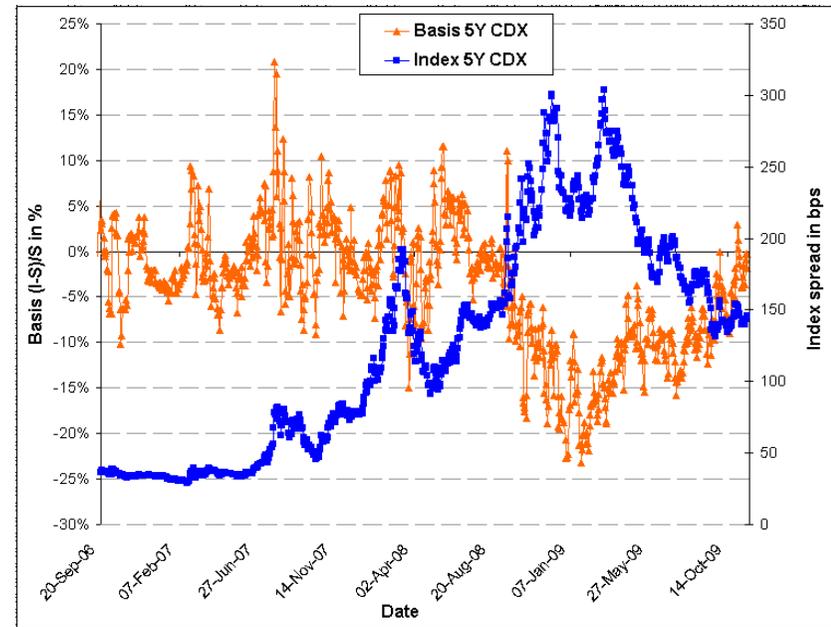
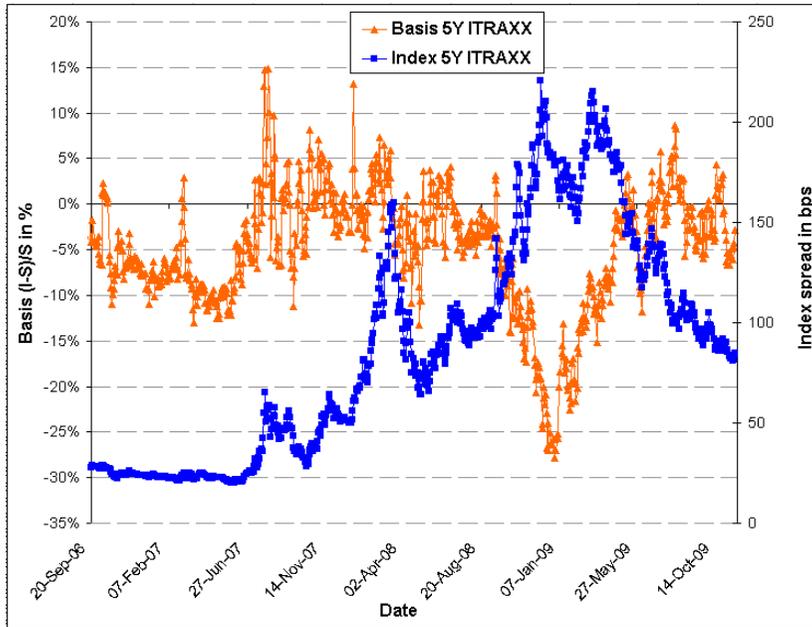
- In spite of general criticisms, a CRM-compliant model would present material benefit to the bank, but a number of challenges present themselves
- What to model for each risk factor and how
  - Choice between model inputs and market observables is often non-trivial (e.g., base correlations vs. tranche prices)
  - Values (levels) or changes in them
  - Match whole distribution or particular range (e.g., tail)
- Dependence between factors is crucial
  - Well-documented empirical evidence of correlation between some of the factors (e.g., spreads and recovery rates)
  - Overall correlation vs. tail dependence
  - Calibration of factors is not independent: e.g., given spreads and recovery rates, implied correlations are constrained by tranche prices
- Technical
  - Simulated values for risk factors may need to satisfy complicated no-arbitrage conditions
  - Simplified and/or accelerated pricers to be used for the complicated products involved, given the number of evaluations required

# Empirical dependencies in CRM (1)

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- Negative correlation between default rates and recovery rates
  - Altman et al (2005) were able to explain from 50% to 80% of default rate variance by recovery rates (depending on choice of variables)
  - BNP Paribas internal study (2009) finds a strong correlation (-66%) between realised annual default frequencies and recovery rates of US corporates, reaching -72% in times of recession
  - Based on US corporate bond data since 1980s
  - Probably illustrates a common driver behind high default rates and low recoveries (crisis scenario)
  - Arguably, may be of limited use when looking at recovery rates as a tranche pricing parameter in “normal” markets – but may still be appropriate in tail scenarios
  - Default rates in CRM reflected in migrations (“IRC part”) and any extra spread dynamics (“spread volatility part”)
- Spreads and migrations
  - Intuitively, downgrades are associated with widening and upgrades, with tightening of spreads
  - Seems to imply negative correlation between asset returns and spreads
  - However the correct dynamics are far less obvious: if rating actions trail the market, downgrade is likely to be already “priced in” (avoid double counting)

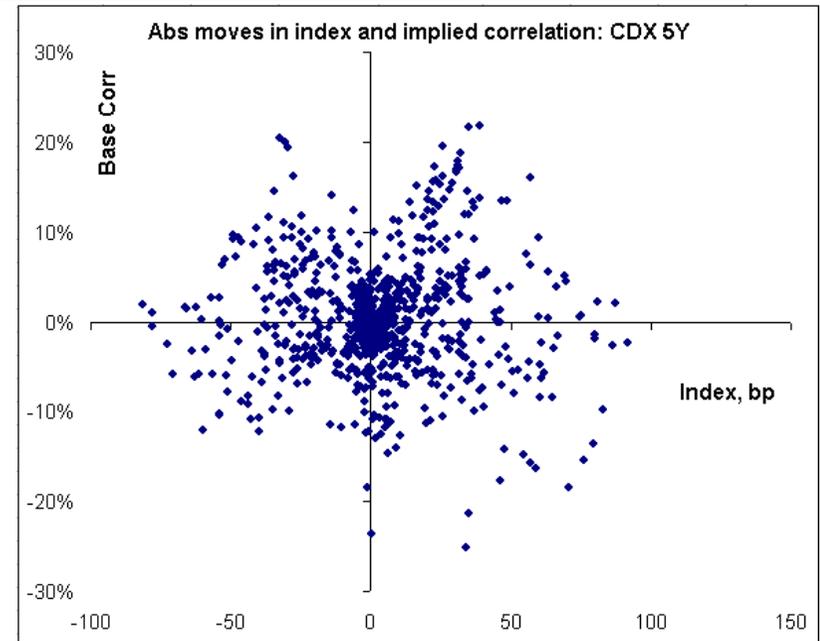
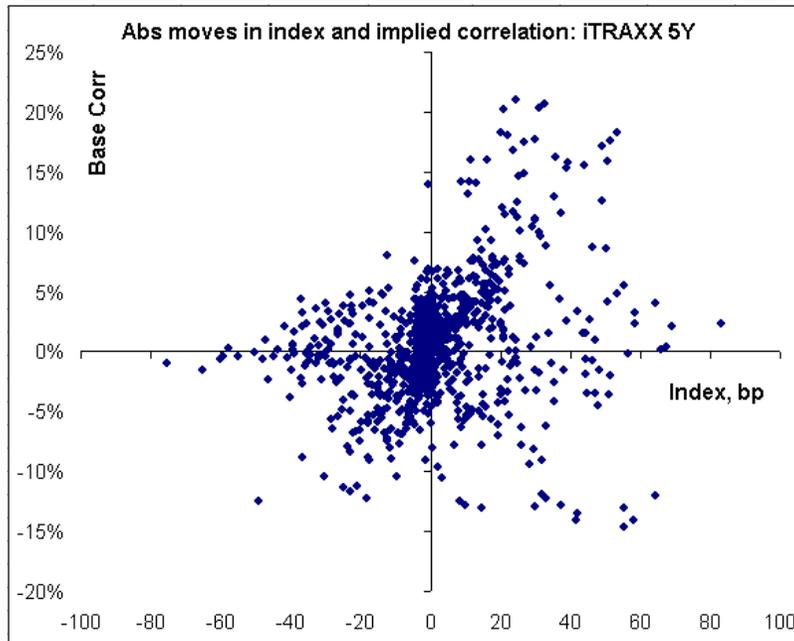
# Empirical dependencies in CRM (2): spreads-basis



## ■ Spreads and index-constituent basis

- In figures above, negative value for basis means names are wider than index
- Different behaviour in quiet markets and turbulent/directional markets
  - Expect index to be tighter than names due to better liquidity in normal times
  - Idiosyncratic/industry/regional events: names may widen faster than index
  - Global crisis/widening: index widens much faster
- May argue for small positive or significant negative correlation between index level and basis, depending on scenarios to be captured
- Ultimate model decision to be based on tail scenarios and may not be possible to make upfront

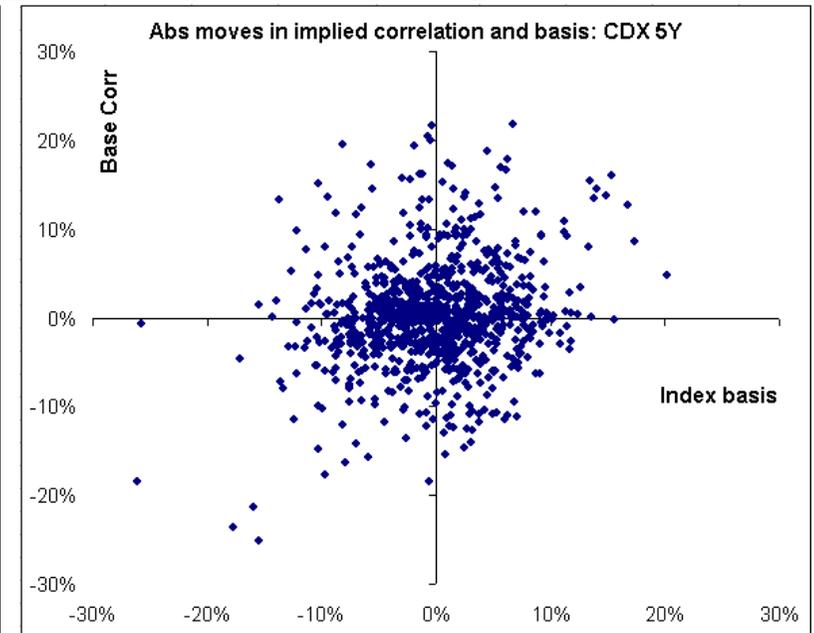
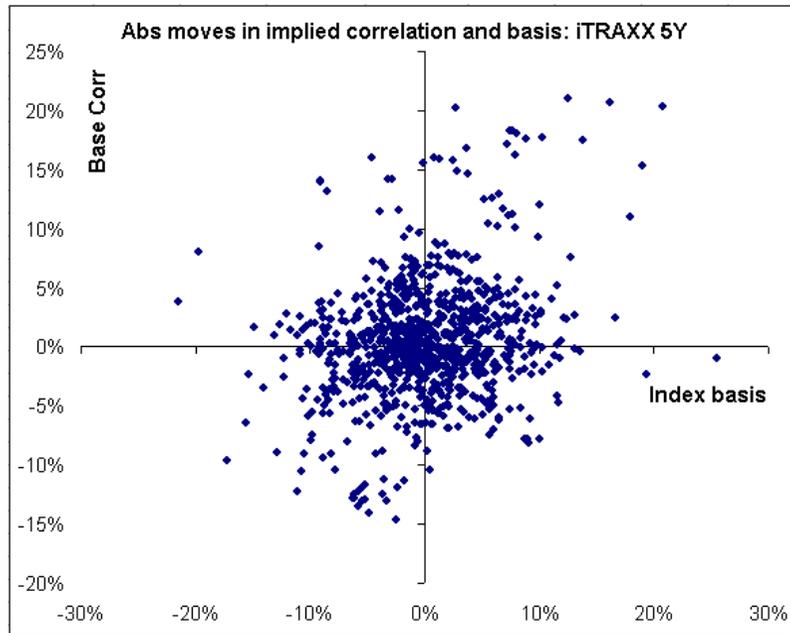
# Empirical dependencies in CRM (3): spreads-correlations



## ■ Spreads and implied correlations

- Figures above show scatter plots of 1-month moves in index spreads and mezzanine base correlations since 2006
- Picture is largely similar for equity and senior base correlations, and also between relative moves
- No pronounced dependence pattern emerges (especially for CDX), suggesting very weak link between spreads and implied correlations
- It is entirely possible that dependence is simply more complicated and nonlinear

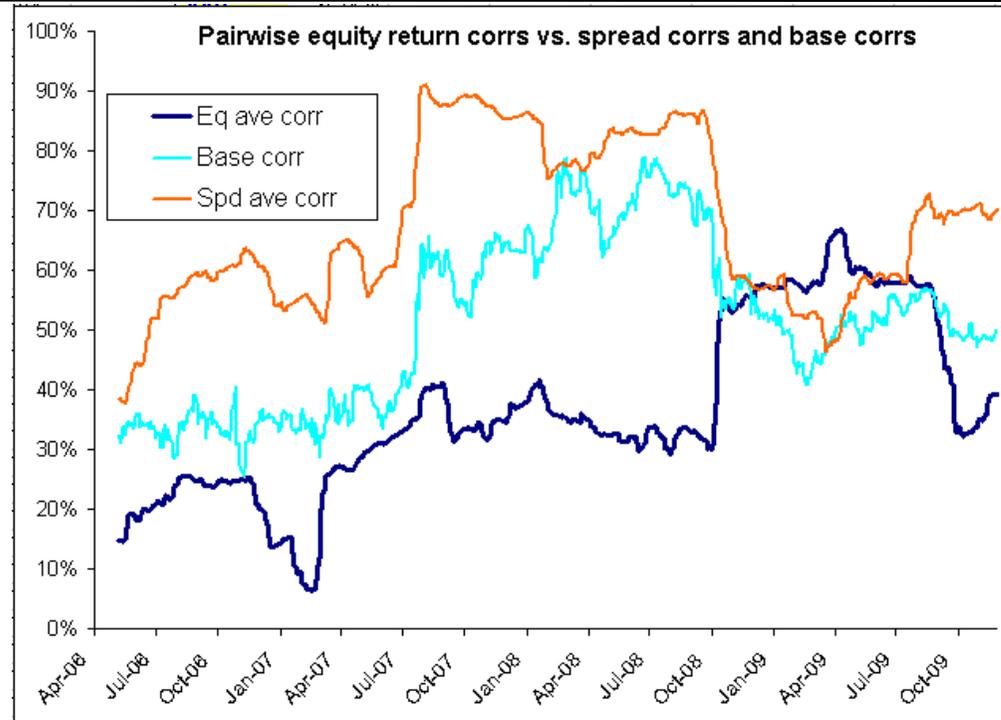
# Empirical dependencies in CRM (4): correlations-basis



## ■ Implied correlations and index basis

- Figures above show analogous scatter plots, but for implied correlations against index basis
- In this case, there is much less foundation for any direct links – and none is observed
- Does visual similarity of plots mean a similar level of dependence? The answer to this question may be the difference between a correct model specification and a wrong one

# Empirical dependencies in CRM (5): correlations



## ■ Implied correlations versus realised correlations

- Asset return model implicitly introduces correlation between defaults, yet base correlations also relate to default correlation in the model
- This apparent disconnection is akin to realised versus implied volatility
- Look at historical time series of realised (asset return) correlations and implied (base) correlations, taking equity or spread returns as proxy for the former
- Data is inconclusive, except perhaps for propensity for common “jumps”, but even the direction is not obvious



# Modelling objects for CRM (1)

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- Three main approaches to choosing risk factors
  - Model directly the inputs into pricing functions
  - Model market observables (quotes, prices)
  - Model artificial quantities which map well to either of the above
- Neither is unconditionally superior, but certain common considerations/concerns enter the picture
- Natural bounds for parameter values
  - For example, implied default correlations and recovery rates must be in  $[0, 1]$ , spreads must be positive, etc.
  - May loosen or even lift some of these conditions by modelling increments/returns
  - Choose underlying stochastic model to produce bounded output by construction
  - Post-simulation adjustment, assuming probability of violating constraints is small
- No-arbitrage constraints
  - Not all sets of simulated parameters would produce arbitrage-free prices
  - This is equally true of pricing inputs (e.g., correlations or hazard rates) as of market observables (tranche prices or spreads)
  - Necessary or sufficient conditions may not be easy to express in the chosen parameter space; when more than a single parameter set is involved, this can become prohibitive



## Modelling objects for CRM (2)

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- Speed of getting from simulation to PV
  - If pricing inputs are simulated, this can be trivial
  - Otherwise, potentially costly re-bootstrapping needs to be performed “on the fly”
- Calibration
  - Stochastic models for both pricing inputs and market quotes can be calibrated, e.g., to historical evolution parameters or, if preferred, to a particular period of interest
  - Calibrated parameters, such as standard deviation or some tail measure, should be relatively straightforward to interpret and check
  - This may not be true of mapped quantities (see example below), which are less intuitive and less amenable to interpretation
- **Example:** implied correlation for CDO tranches
  - Pricing input: base correlations
    - must be bounded between 0 and 1; may use a bounded distribution or apply cap/floor
    - very pricing-model-dependent; no-arbitrage conditions hard to enforce in isolation
  - Market observable: standard index tranche prices
    - no restrictive bounds, but need to recalibrate base correlations on the fly to produce PV
    - still not immediately obvious how to make sure prices form an admissible set
  - Mapped quantity: equity tranche loss (cf. “index loss fraction” in Kainth et al (2010) )
    - ideal for no-arbitrage conditions, but still a manipulation away from PV function input
    - calibration harder to perform and interpret



# Risk factor modelling

- Having decided on the quantities to model as risk factors, technical modelling approach must be chosen
- Non-parametric or semi-parametric fit
  - Look at time series of chosen factor or its increments / returns over certain window
  - Fit distribution or estimate parameters of likely distribution (e.g., mean and variance)
  - For multi-dimensional risk factors, e.g., “tenor” and “strike” dimensions:
    - model each tenor-strike combination separately, introduce intra-dependence
    - reduce dimension, e.g., by statistical tools such as PCA
    - first approach gets cumbersome quickly; second approach lets the data take control
  - Such approaches as PCA may perform well, but judgement and interpretation of signals by risk managers is severely reduced, making it very difficult to be proactive
- Parametric analysis
  - Choose stochastic drivers for each factor: single values or curve / surface characteristics, such as level, slope, curvature, etc. (parameterise)
  - Assume a tractable model, amenable to calibration; introduce dependence
  - Use stochastic model outputs to calculate observable quantities (market prices or quoted values) and fit parameters to reproduce realised time series
  - This way we have more control of the model, but become more sensitive to validity of initial assumptions
  - Fitting distribution and especially dependence parameters may be a tricky process

# Fitting tails: Extreme Value Theory (EVT)

- EVT is a long-established method for estimating tails of distributions, with applications to excess loss modelling in insurance and finance
- Two main sets of methods are used to analyse univariate extremes
  - **Block Maxima** method looks at the distribution of maximum values over large samples (“blocks”) of observed parameter values
  - **Peaks-over-Threshold** (POT) method looks at the distribution of all observed values above a suitably high boundary (“threshold”)
  - POT are considered superior since they use the [limited] extreme observations more efficiently
- Two classes of limiting distributions
  - Generalised Extreme Value (GEV) distributions appear in the Block Maxima method

$$H_{\xi}(x) = \begin{cases} \exp\{-(1 + \xi x)^{-1/\xi}\}, & \text{if } \xi \neq 0, \\ \exp\{-e^{-x}\}, & \text{if } \xi = 0 \end{cases}$$

- Generalised Pareto (GP) distributions appear in the POT method

$$G_{\xi}(x) = \begin{cases} 1 - (1 + \xi x)^{-1/\xi}, & \text{if } \xi \neq 0, \\ 1 - e^{-x}, & \text{if } \xi = 0 \end{cases}$$

# EVT: some maths and fundamental results\*

## ■ Maximal domain of attraction (MDA):

- Suppose  $X_k \sim F$  are i.i.d. random variables. Denote  $M_n = \max(X_1, \dots, X_n)$
- Suppose that one can find sequences  $c_n > 0$  and  $d_n$  and distribution function  $H$  such that

$$\frac{M_n - d_n}{c_n} \xrightarrow{d} H \quad \text{as } n \rightarrow \infty$$

- Then  $F$  belongs to the maximal domain of attraction of  $H$ :  $F \in \text{MDA}(H)$

## ■ Fisher-Tippett Theorem, limit theorem for maxima, “the CLT of EVT”

- Suppose  $X_1, X_2, \dots \sim F$  are iid, and for some non-degenerate distribution function  $H$ ,  $F \in \text{MDA}(H)$ . Then  $H$  is GEV:  $H(x) = H_\xi((x - \mu)/\sigma)$  for some  $\xi, \mu$  and  $\sigma$ .
- Can be generalised for non-iid random variables; is stable with respect to block size
- Most known distributions belong to MDA of GEV distributions for different  $\xi$ :
  - normal, lognormal, exponential, gamma are in MDA of  $H_0$  (a.k.a. Gumbel)
  - Student-t, Pareto are in MDA of  $H_\xi$  with  $\xi > 0$  (a.k.a. Fréchet)
  - uniform, beta are in MDA of  $H_\xi$  with  $\xi < 0$  (a.k.a. Weibull)

## ■ The analogue for POT is Pickands-Balkema-de Haan Theorem:

- With same assumptions as above, there exists a measurable function  $\beta(\cdot)$  such that

$$\lim_{u \rightarrow x_0} \sup_{0 \leq x < x_0 - u} \left| F_u(x) - G_\xi(x/\beta(u)) \right| = 0, \quad \text{where } F_u(x) = \mathbb{P}\{X - u \leq x \mid X > u\}, \quad 0 \leq x < x_0 - u$$

- In other words, limit distribution of the excess is GP and stable with respect to level



# EVT: how to tackle multiple dimensions

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- POT analysis allows to construct estimates of high quantiles of distributions, parametric or empirical, for each risk factor
- EVT in multiple dimensions is neither as straightforward, nor as well-developed
  - Technical:  $n$ -dimensional quantile is not a point, but an  $(n-1)$ -dimensional hypersurface
  - Extensions tend to look at component-wise extremes, rather than joint extremes
- Copula functions present one way of tackling several factors
  - Given the distributions for each risk factor, perform EVT (POT) analysis on each one to obtain the corresponding flavour of GP (or GEV)
  - Represent joint distribution as a chosen copula with GP/GEV marginals
  - Pick a point inside the joint quantile (hypersurface) by combining suitable component-wise quantile
- Choice of the copula will determine the dependence structure
  - Gaussian copula is simple and captures correlation
  - For tail dependence, may consider a multivariate distribution with fatter tails
  - Calibrating to empirical correlation versus dependence in extreme scenarios (tails) may lead to different structures!

# EVT analysis: example set-up

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- We look at the predictions of EVT for the example CDO package described above
- Assume a very simple stochastic model for the price risks
  - “Global” moves for spreads and recoveries (same for all names)
  - Model 5Y maturity only for correlations and indices
  - Normal distribution for spread returns, inspired by mean-reverting diffusion
  - Similar model for multiplicative index basis
  - Bounded distribution for recovery rates
  - Fit historical tails of base correlation curve moves by looking at principal components
- For dependence structure, specify rank correlation (e.g., Spearman’s rho)
  - Assume negative correlation between spreads and recovery rates and positive correlation between spreads and basis; other correlations small
  - Map rank correlation to linear correlation to be used in multivariate normal or Student-t copula
  - Simulate multivariate random variables with copula, then use GP and GEV to approximate the tails
  - Combine component-wise extremes as a point in the n-dimensional tail

# EVT analysis: example results

<b>RISK FACTOR INCREMENT</b>	<b>99.9<sup>th</sup> percentile</b>	<b>0.1<sup>th</sup> percentile</b>
<b>Spread (multiplicative)</b>	32.5	0.001
<b>Recovery (multiplicative)</b>	2.0	0.001
<b>Basis (additive)</b>	46.2%	-37.6%
<b>Base Correlation (additive)</b>		
<i>Strike 1</i>	53.5%	-44.4%
<i>Strike 2</i>	37.3%	-36.5%
<i>Strike 3</i>	34.3%	-35.0%
<i>Strike 4</i>	25.0%	-29.8%
<i>Strike 5</i>	11.8%	-19.5%

- Table above produces the EVT approximations of the 99.9% and 0.1% component-wise quantiles
- The moves do appear quite large – but are they enough/too much for a particular P&L quantile?
- These correspond to losses of EUR 1.5 mm on the sample CDO package



# EVT analysis: critique

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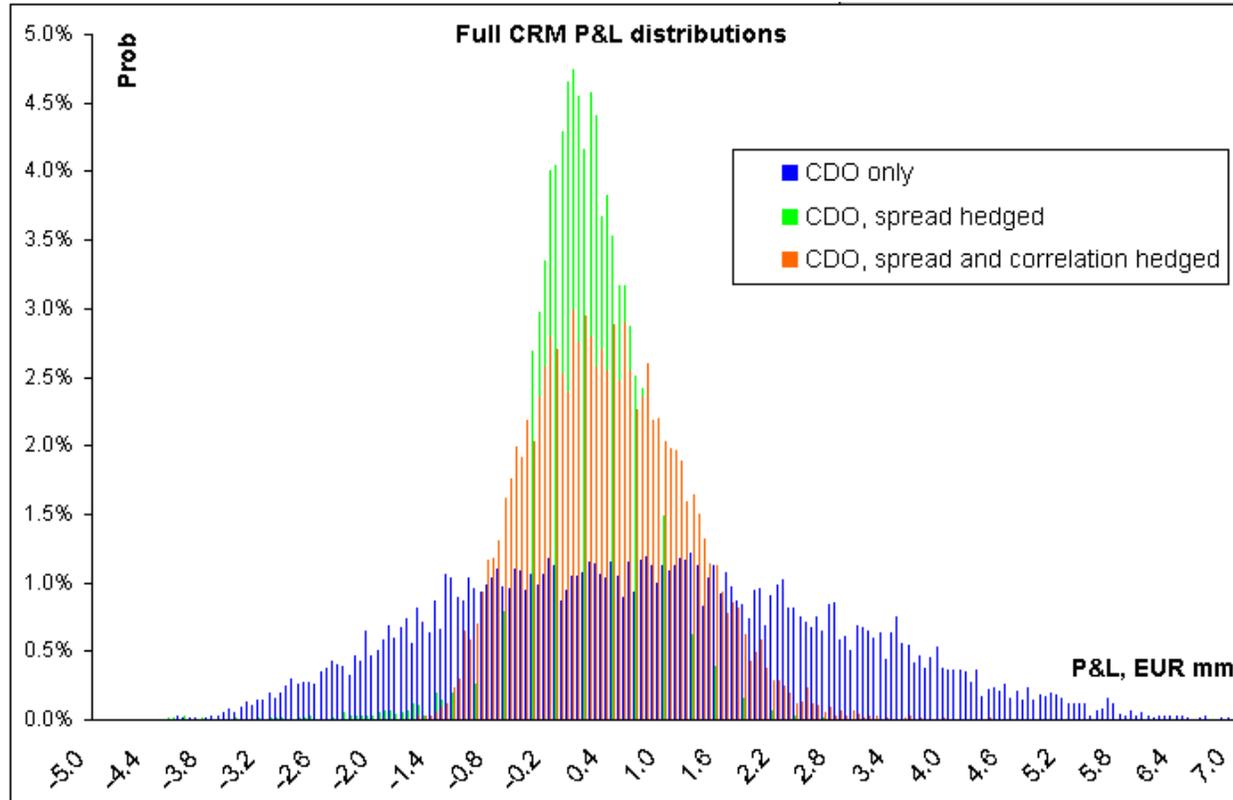
- This analysis can be used as a simple estimate of the result, but has some obvious drawbacks
- Technical
  - Not fully CRM-compliant, as migrations and defaults are not part of the model. Can argue that part of spread move captures migration effect – or introduce a new asset return-like variable
  - Defaults, which are inherently idiosyncratic, cannot really be captured in a “global move” framework. Per-name asset return simulation would increase dimensionality drastically. Can try to come up with an exogenous default-triggering mechanism
  - Applying component-wise tails could be over-conservative, may need full-blown multi-dimensional EVT
- Philosophical
  - Fundamental assumption underlying this approach is that joint extreme realisations of risk factors bring about extreme P&L scenarios
  - While one can argue that worst crises cause huge moves in all markets, it is far from obvious that the required loss percentile will be captured correctly
  - Depending on how well the book is hedged against different risks, tail loss scenarios may be directional in a few, but not necessarily all variables
  - Actual dependence between risk factors may render a joint realisation of sufficiently high/low tail events “too” unlikely



# Moving on from EVT: simulation and revaluation

- Alternative approach: simulation-based model
  - Model increments for all pricing inputs
  - Calibrate to historical short-term moves (e.g., 10- or 20-day) and project to 1-year moves, taking into account estimated mean reversion where necessary
  - Re-use migration/defaults simulation from earlier, add recovery rates, basis, base correlations and extra spread volatility component
  - Match empirical correlation between variables via factor models
- Simulation engine produces scenarios for spreads and recovery rates (per name), basis (per index-maturity) and base correlation surface (per index)
- Ignore ageing of positions and rebalancing of hedges
- Exact revaluation for each scenario gives a PV, which is converted to hypothetical P&L in 1 year by subtracting the current PV
- Now we can calculate the tail of the P&L, and not of joint risk factor distribution, which is more in line with the CRM objective
- Can look at the effect of hedges on CRM by comparing figures for fully hedged “package” and partially open position (e.g., with no correlation hedge)
- Can also investigate which scenarios caused the losses at 99.9<sup>th</sup> percentile

# Generic example: full CRM results



<b>P&amp;L DISTRIBUTION STATISTICS</b>			
<i>(EUR, mm)</i>	<b>CDO only</b>	<b>CDO + spread hedge</b>	<b>CDO + spread &amp; corr hedge</b>
<b>Minimum</b>	-4.2	-4.3	-2.1
<b>Maximum</b>	7.0	3.2	4.4
<b>Mean</b>	0.8	0.2	0.4
<b>Std deviation</b>	2.0	0.6	0.8
<b>CRM charge</b>	<b>3.7</b>	<b>2.9</b>	<b>1.4</b>
<b>Standard charge</b>	1.9	56.0	69.1
<b>Floor</b>	<b>0.2</b>	<b>4.5</b>	<b>5.5</b>

# Discussion of results (1)

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- CRM displays the correct behaviour with respect to reduction of risk
  - Naked tranche incurs the largest charge
  - Spread and correlation hedges progressively reduce the charge
  - P&L distribution becomes less disperse as we add hedges: probability of extreme moves goes down as we reduce risk
  
- Analyse types of scenarios causing tail loss
  - **Adverse credit markets**: up to 60 defaults, severe spread widening, large negative basis, with or without move in correlation (outside of senior tranches)
  - **Fast tightening of credit**: spreads come in, index even faster; with or without correlation moves
  - Other: iTRAXX-CDX correlation moves in different directions; large moves in basis and/or correlations; recovery rates appear to be generally less important
  - Note that for directional positions, tail scenarios exploit the exposure:
    - large correlation move scenarios for the position without index tranches
    - extreme spread move scenario for the position without single-name CDS hedge

# Discussion of results: extremes and floor

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- We see that extreme P&L moves are not necessarily caused by tail realisations for all marginals
  - Take a closer look at 0.5% largest-loss scenarios
  - Only a few are caused by very extreme risk factors realisations, e.g.:
    - 40% correlation move + 15% tightening of the basis in CDX, coupled with 10% of name either tightening or widening by more than a factor of 5
    - smaller correlation move (10-20%), but in both markets and in opposite directions, coupled with extreme spread moves in both directions and basis tightening globally
  - More typical scenarios: large, but not necessarily extreme move in one market (e.g., spreads or correlation in Europe or US only), with little or no move in other variables
  - We note at least 10 defaults in almost any tail scenario
  
- Note as well that the dynamics of the floor, based on standardised method, are completely wrong
  - Notional-based with no netting for different instruments, so hedging incurs a larger charge
  - Underestimates the risk on an outright position, overestimates the risk on hedged position, as compared to CRM – very significantly!

# CRM in broader risk management context

- Introduction of the banking book based floor has significantly undermined the value of CRM
  - CRM charge on a typical correlation book is dominated by the floor and not by the model-based figure
  - Normal trading activity involves hedging risks, but this is not recognised by the floor
  - CRM model, however, does allow to use  $\alpha$  (standardised charge), the alternative being to move correlation trades to securitisation and incur full banking book charge
  - The concern is that market activity will be focused around capital arbitrage and not sound risk management, as must have been the regulators' intention
- CRM and VaR
  - Correlation trading books are still subject to VaR-based risk calculation
  - Currently a sensitivity-based approach is common, with alternatives based on history or conservative simulations
  - A CRM-compliant model can be enhanced to create a better VaR engine
    - can add more risk factors as necessary
    - calibrate model parameters using 10-day moves to calculate 10-day VaR
    - risk factor dependence is already captured better than in most live VaR systems
    - more exact than sensitivity-based approach, since full revaluation is used, albeit with simplified pricers
- CRM may become more useful tool, in addition to originally intended purpose

# Conclusions

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- Building a consistent CRM-compliant model presents a number of challenges
  - Choosing most convenient variables to model can be tricky
  - Correct dependence is not easy to capture
  - No-arbitrage conditions are not straightforward
- Simultaneous extreme realisations of risk factors may not be the scenarios that cause extreme loss at the correct percentile
- Introduction of a floor based on standardised method, not suitable for trading books, substantially reduces the value of CRM for capital and creates poor incentives, discouraging good risk management practices
  - Risk-reducing hedges do not decrease, but often increase the floor
  - Resulting capital charge for complex correlation trades and their hedges is dominated by the floor, and model-based CRM is unlikely to be reported
- Potential additional use for CRM model is more accurate calculation of VaR for existing correlation trading positions



## Appendix: some EVT references

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- Embrechts, Resnick & Samorodnitsky (1997): “Extreme value theory as a risk management tool”
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- Chavez-Demoulin & Embrechts (2009): “An EVT primer for credit risk”
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