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Synthetic Credit Tranches Teach-In

Just in case…

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That difficult? Really?

“Understanding the credit risk profile of CDO tranches poses challenges even to the most sophisticated participants”

Alan Greenspan, chairman of the US Federal Reserve (*Financial Times*, 2005)

Judge for yourself…

Agenda

- **Introduction, mechanics and cash flows**
- What trades? Standard vs. Bespoke tranches
- History of the tranche market
- Resources at Citi
- Splitting risks: Market/systemic vs. default/idiosyncratic risks
- Tranche risk exposures
- Delta-hedging
- Popular strategies
- Pricing
- Other topics

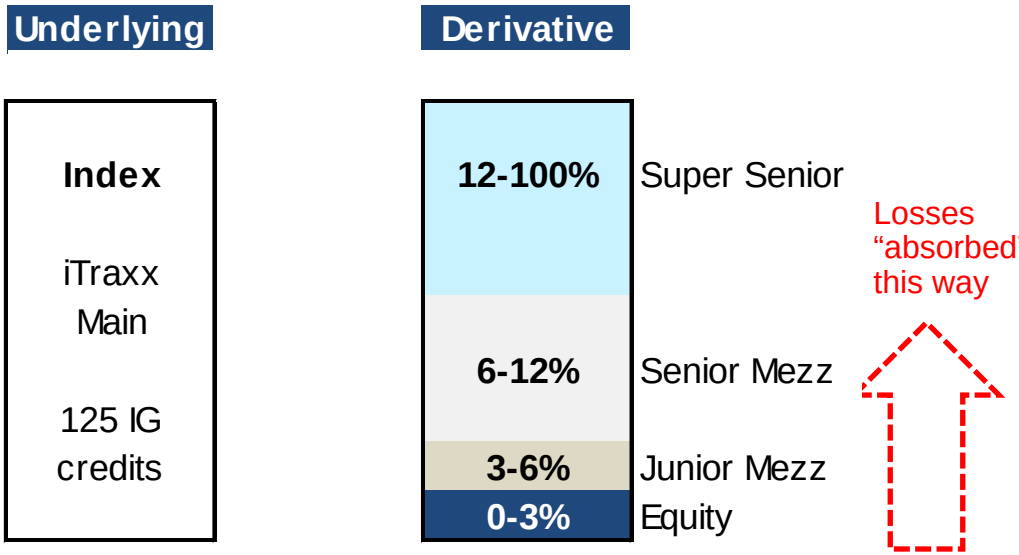
Agenda

- Introduction, mechanics and cash flows
  - **What defines a tranche?**
  - Cash flows 1: Tranche losses
  - Cash flows 2: Tranche upfront + coupon
  - What's in a run?

What defines a tranche?

- **Tranches are synthetic instruments with payoffs based on the (realised) default losses on an underlying credit portfolio**
  - Like single name CDS and CDS indices, investors can take both long and short (risk) exposures on an unfunded fashion.
- Each tranche is characterised by:
  - **Underlying credit portfolio** – A synthetic portfolio (e.g. a standard CDS index like iTraxx Main or a "bespoke" portfolio of CDS).
  - **Attachment and detachment points** – "Range" of portfolio default losses the tranche is exposed to.
    - E.g. 3% to 6% - where 3% is the attachment and 6% is the detachment.
      - A 3-6% tranche will "absorb" portfolio losses from 3% to 6%.
    - Tranches are classified as "equity", "mezzanine" or "senior" on this basis.
    - Junior tranches have lower attachment/detachments than senior tranches.
  - **Maturity** – Like CDS and CDS indices, but unlike CLO tranches, tranches have a hard maturity (no reinvestment features etc).
  - **Trading & quoting conventions** – How does an investor taking risk get compensated? How does an investor hedging pay?
    - Trading convention – Via an Upfront (%) plus a fixed (running) coupon (%) on the notional at risk.
      - The same way single name CDS and CDS indices trade.
    - Quoting convention – How are tranches quoted?
      - Like CDS and indices, tranches can be quoted on (i) Upfront, (ii) Flat spread, or (iii) Price.
    - We next use standard iTraxx Main tranches to illustrate these concepts.

Underlying portfolio and attachment-detachment points



Index = 0-100% tranche

- Tranche attachment and detachment points:

  An X-Y% tranche absorbs portfolio losses from X to Y%

  - No default losses as long as portfolio losses are below X%.
  - Absorbs all portfolio default losses from X to Y%.
  - Fully "wiped-out" for portfolio default losses above Y%.

Defaults and index default losses

- Each default generates an index (portfolio) loss equal to:

  (1 – Recovery) x Weight in the index

- iTraxx Main is an equally weighted portfolio of 125 CDS:
  - Weight = 0.8% = 1 / 125
  - Assume a 40% recovery
  - Index loss for 1 default = 0.48%.
  - As defaults occur, index losses increase:

Default	Weight	Assumed Recovery	Loss	Cum. Index Loss
1	0.8%	40%	0.48%	0.48%
2	0.8%	40%	0.48%	0.96%
3	0.8%	40%	0.48%	1.44%
4	0.8%	40%	0.48%	1.92%
5	0.8%	40%	0.48%	2.40%
…	…	…	…	…
10	0.8%	40%	0.48%	4.80%
…	…	…	…	…
20	0.8%	40%	0.48%	9.60%
…	…	…	…	…
125	0.8%	40%	0.48%	60%

Source: Citi Research

What defines a tranche? iTraxx Main S21 Example

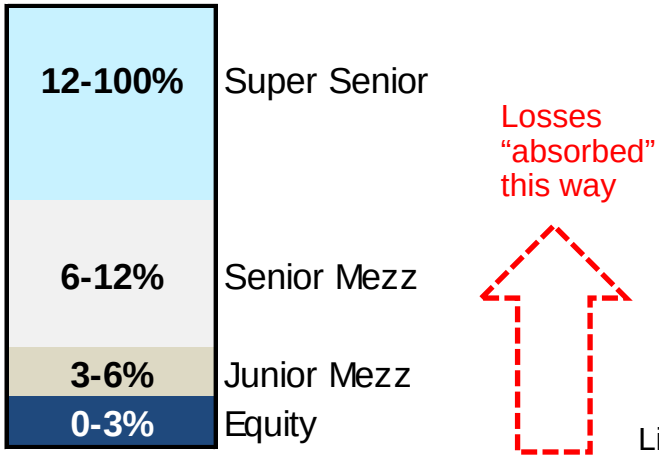
Underlying portfolio

- **iTraxx Europe Main S21**
  - Equally weighted portfolio of 125 credits
  - European investment grade companies
  - Diversified across sectors and countries

Traded maturities

- **Jun-17** and **Jun-19** traded

Attachment & Detachment structure



Trading & Quoting Conventions

- Traded/quoted similarly to single name and Indices
- Tranches **trade with upfront +fixed coupon**
- **Quoting standards**:
  - Upfronts are quoted for junior tranches
  - Senior tranches are quoted in flat spread terms (which can be converted into an upfront using CDSW/QCDS and a pre-agreed recovery assumption).

Jun-17	Upfront	Coupon	Flat Spread	Quoted	Recovery Assumption*
0-3%	**17.22%**	1.00%	695	Upfront	
3-6%	**1.52%**	1.00%	148	Upfront	
6-12%	-0.90%	1.00%	**72**	Spread	0%
12-100%	-2.72%	1.00%	**15**	Spread	40%
Ref (Index)	-1.87%	1.00%	**42**	Spread	40%

Prices as of 3-Apr-14. * For tranches quoted in spread.

Like in an index position, default losses are settled as they happen.

Source: Citi Research

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Portfolio / Index Default Losses

- **Assume there is a default in the iTraxx Main with a 40% recovery rate**
  - The weight of each name in the index is 0.8% = 1 / 125.
  - Thus, with a 40% recovery rate, the default loss in the index would be 0.48% = 0.8% x (1 – 40%).
- **One default generates a 0.48% index loss with 40% recovery**
  - Lower recoveries will generate a larger loss

Number of index defaults	Index weight	40% Recovery Index loss	40% Recovery Cummulative Index Loss	0% Recovery Index loss	0% Recovery Cummulative Index Loss
1	0.8%	0.48%	0.48%	0.80%	0.80%
2	0.8%	0.48%	0.96%	0.80%	1.60%
3	0.8%	0.48%	1.44%	0.80%	2.40%
4	0.8%	0.48%	1.92%	0.80%	3.20%
5	0.8%	0.48%	2.40%	0.80%	4.00%
6	0.8%	0.48%	2.88%	0.80%	4.80%
7	0.8%	0.48%	3.36%	0.80%	5.60%
8	0.8%	0.48%	3.84%	0.80%	6.40%
9	0.8%	0.48%	4.32%	0.80%	7.20%
10	0.8%	0.48%	4.80%	0.80%	8.00%
…	…	…	…	…	…
20	0.8%	0.48%	9.60%	0.80%	16.00%
…	…	…	…	…	…
30	0.8%	0.48%	14.40%	0.80%	24.00%

Source: Citi Research

How are index default losses distributed across tranches?

- Let's take the 0-3% and 3-6% tranches as examples and compute their losses as defaults in the index increase:

		0-3%			3-6%		
Number of index defaults	(40% Rec) **Cummulative Index Loss**	**Index losses absorbed**	**Losses on tranche traded notional**		**Index losses absorbed**	**Losses on tranche traded notional**	
1	0.48%	0.48%	16%	Hit	0.00%	0%	
2	0.96%	0.96%	32%		0.00%	0%	
3	1.44%	1.44%	48%		0.00%	0%	
4	1.92%	1.92%	64%		0.00%	0%	
5	2.40%	2.40%	80%		0.00%	0%	
6	2.88%	2.88%	96%		0.00%	0%	
7	3.36%	3.00%	100%	Wiped out	0.36%	12%	Hit
8	3.84%	3.00%	100%		0.84%	28%	
9	4.32%	3.00%	100%		1.32%	44%	
10	4.80%	3.00%	100%		1.80%	60%	
11	5.28%	3.00%	100%		2.28%	76%	
12	5.76%	3.00%	100%		2.76%	92%	
13	6.24%	3.00%	100%		3.00%	100%	Wiped out
14	6.72%	3.00%	100%		3.00%	100%	

16% = 0.48% index loss / 3% tranche width

12% = 0.36% index loss / 3% tranche width

Default losses are settled as they happen.

- Assuming a 40% recovery you need 7 defaults to wipe out the equity tranche and hit the 3-6% tranche, and 13 to wipe out the 3-6%.
- Important: **The actual notional loss on your tranche notional depends on its width**.
  - E.g. the first default generates a 0.48% index loss, fully absorbed by the equity tranche.
  - That **default** generates a **loss** on the **equity** tranche equal to **16% = index loss (0.48%) / tranche width (3%)**.

Source: Citi Research

How many defaults needed to hit / wipe-out a tranche?

- Defaults needed to hit a tranche:
  - **Tranche attachment / index loss generated by 1 default (which is 0.48% for a 40% recovery)**
- Defaults needed to wipe-out a tranche:
  - **Tranche detachment / index loss generated by 1 default (which is 0.48% for a 40% recovery)**

- Let's take the 3-6% tranche and assume a 40% recovery rate:
  - The tranche will be hit with the 7th default: 3% / 0.48% = 6.25, which we round to 7
  - The tranche will be wiped out with the 13th default: 6% / 0.48% = 12.5, which we round to 13

	40% Recovery		0% Recovery	
Tranche	**Hit**	**Wipe-out**	**Hit**	**Wipe-out**
0-3%	1	7	1	4
3-6%	7	13	4	8
6-9%	13	19	8	12
9-12%	19	25	12	15
12-22%	25	46	15	28
22-100%	46		28	

Source: Citi Research

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Tranche outstanding notional

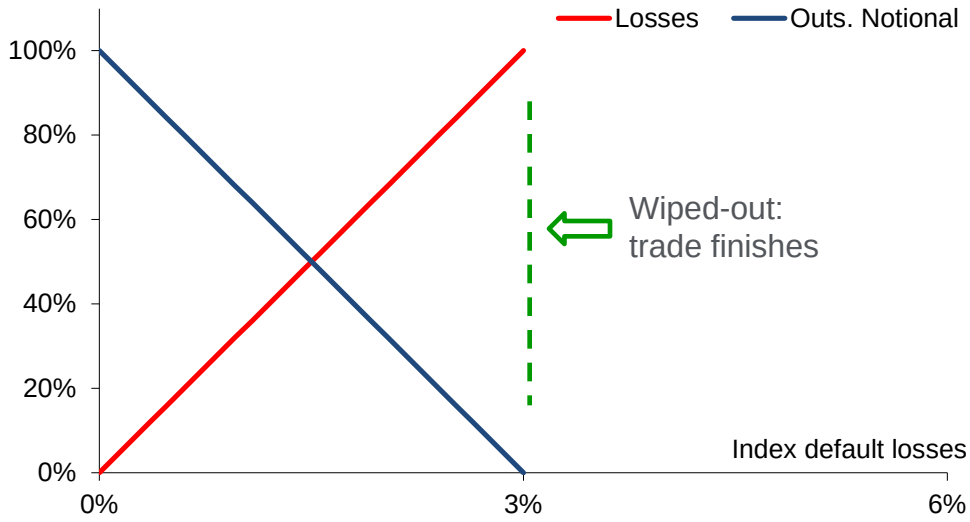
- **Tranche losses are paid as and when they happen. How is the compensation to bear those losses received?**
  - The **tranche upfront** is received at **inception** of the trade, on the initial tranche notional traded
  - The fixed **coupon** is received quarterly, **on the outstanding tranche notional at each point in time**
    - The **tranche outstanding notional is equal to the initial notional minus the losses suffered by the tranche***
    - Outst. notional is 100% of initial notional until the tranche is hit, and progressively falls to 0 as the tranche absorbs losses.
    - Once the tranche is wiped out (index default losses > detachment), the outst. notional is zero and the trade terminates.

		0-3%			3-6%		
Number of index defaults	(40% Rec) Cummulative Index Loss	Index losses absorbed	Losses on tranche traded notional	Tranche Outstanding Notional	Index losses absorbed	Losses on tranche traded notional	Tranche Outstanding Notional
1	0.48%	0.48%	16%	84%	0.00%	0%	100%
2	0.96%	0.96%	32%	68%	0.00%	0%	100%
3	1.44%	1.44%	48%	52%	0.00%	0%	100%
4	1.92%	1.92%	64%	36%	0.00%	0%	100%
5	2.40%	2.40%	80%	20%	0.00%	0%	100%
6	2.88%	2.88%	96%	4%	0.00%	0%	100%
7	3.36%	3.00%	100%	0%	0.36%	12%	88%
8	3.84%	3.00%	100%	0%	0.84%	28%	72%
9	4.32%	3.00%	100%	0%	1.32%	44%	56%
10	4.80%	3.00%	100%	0%	1.80%	60%	40%
11	5.28%	3.00%	100%	0%	2.28%	76%	24%
12	5.76%	3.00%	100%	0%	2.76%	92%	8%
13	6.24%	3.00%	100%	0%	3.00%	100%	0%
14	6.72%	3.00%	100%	0%	3.00%	100%	0%

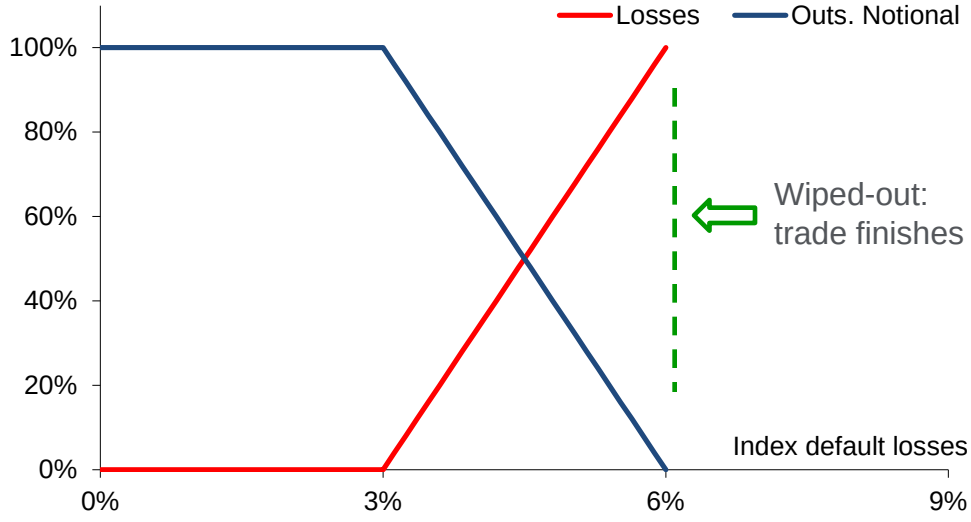
Source: Citi Research. * Except for the super senior tranche (X-100%), see section in “Other topics”.

Tranche losses & outstanding notional

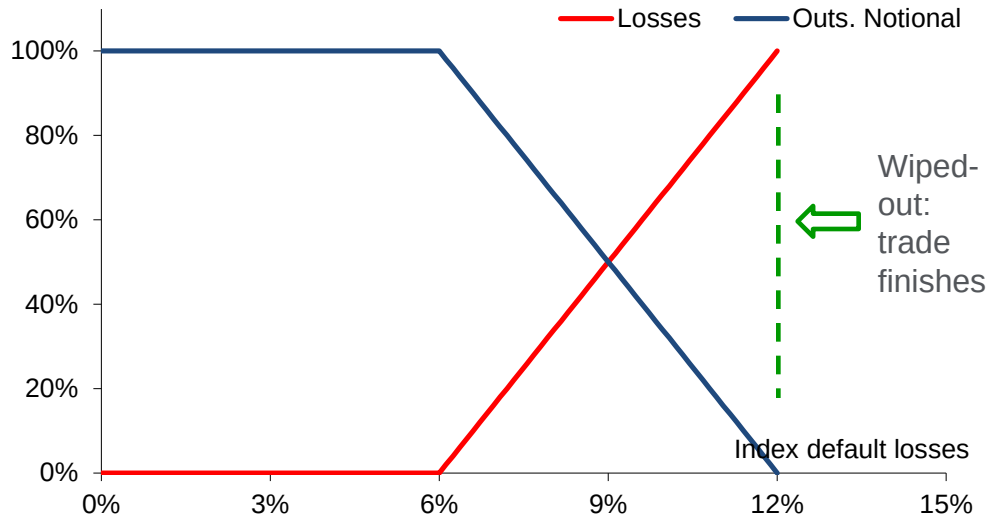
0-3% Tranche



3-6% Tranche



6-12% Tranche



Source: Citi Research

Cash Flow Example

- We sell 100€ Main S21 Jun-17 3-6% protection, receiving 2% upfront and 1% annual coupon, on 16th-Apr-14.
- We experience one default at the end of each quarter going forward until the tranche is wiped out. Assume a 40% recovery rate.

Total Defaults	13								Total Sum CFs	
										-95.60 €
Date	Defaults	Index Loss	Accumulated Index Loss	Accumulated Tranche Loss	Tranche Outstanding Notional	Upfront	Tranche Default CFs	Coupons	Date	Total CFs
Apr-14	0	0.00%	0.00%	0.0%	100.0%	2 €	0 €	-0.07 €	Apr-14	1.93 €
Jun-14	1	0.48%	0.48%	0.0%	100.0%	0 €	0 €	0.25 €	Jun-14	0.25 €
Sep-14	1	0.48%	0.96%	0.0%	100.0%	0 €	0 €	0.25 €	Sep-14	0.25 €
Dec-14	1	0.48%	1.44%	0.0%	100.0%	0 €	0 €	0.25 €	Dec-14	0.25 €
Mar-15	1	0.48%	1.92%	0.0%	100.0%	0 €	0 €	0.25 €	Mar-15	0.25 €
Jun-15	1	0.48%	2.40%	0.0%	100.0%	0 €	0 €	0.25 €	Jun-15	0.25 €
Sep-15	1	0.48%	2.88%	0.0%	100.0%	0 €	0 €	0.25 €	Sep-15	0.25 €
Dec-15	1	0.48%	3.36%	12.0%	88.0%	0 €	-12 €	0.25 €	Dec-15	-11.75 €
Mar-16	1	0.48%	3.84%	28.0%	72.0%	0 €	-16 €	0.22 €	Mar-16	-15.78 €
Jun-16	1	0.48%	4.32%	44.0%	56.0%	0 €	-16 €	0.18 €	Jun-16	-15.82 €
Sep-16	1	0.48%	4.80%	60.0%	40.0%	0 €	-16 €	0.14 €	Sep-16	-15.86 €
Dec-16	1	0.48%	5.28%	76.0%	24.0%	0 €	-16 €	0.10 €	Dec-16	-15.90 €
Mar-17	1	0.48%	5.76%	92.0%	8.0%	0 €	-16 €	0.06 €	Mar-17	-15.94 €
Jun-17	1	0.48%	6.24%	100.0%	0.0%	0 €	-8 €	0.02 €	Jun-17	-7.98 €

Accrued coupon

Every quarter

Assumed timing of defaults: 1 per quarter

Tranche is hit

Tranche is wiped-out, outstanding notional goes to 0%

1% coupon x ¼ (i.e. one quarter) x Outs. Notional

Source: Citi Research

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What's in a run?

iTraxx Main S21 Tranche Run As of 4 April 2014

Maturity

Index spread "Ref"

Index & Series

ITRAXX21 06/17 (40 Mid)		Delta	Lst Close	SpdClsMv	SECBid SECAsk
0-3	15.625/16.625	10.7X	-0.07	-2.5	634 671
3-6	0.625/1.625	4.3X	+0.03	+1.0	120 151
6-12	60/70	2.1X	-0.1	-0.1	60 70
12-100	13.625/16.625	0.5X	+0.38	+0.4	13.62 16.62
ITRAXX21 06/19 (71 Mid)		Delta	Lst Close	SpdClsMv	SECBid SECAsk
0-3	33.625/34.875	6.6X	-0.08	-2.5	909 947
3-6	9.625/10.875	4.4X	-0.05	-1.0	299 326
6-12	161/176	2.6X	-0.3	-0.3	161 176
12-100	32.625/34.375	0.55X	+0.2	+0.2	32.62 34.37

Tranches

Quotes:

Upfronts (%) - junior tranches

and

Flat spreads (bp) - senior tranches

Deltas: Agreed by all dealers daily

Equivalent flat spreads

(SEC = Standard European Contract)

Source: Bloomberg, Citi

What's in a Run? – Index "Ref"

- **The convention is to trade tranches "with delta exchange"** – at the level quoted in the run.
- **This "Ref" is the index spread which has been used to price the different tranches in the run.**
- **It is generally the mid of the index spread at the time the run is sent.**
- Example: An investor buys 100m of Jun-17 3-6% with 4.3x delta exchange.
  - The investor is entered into the tranche, receiving 0.625% upfront (625k) and 1% annual coupon (1m).
  - The investor buys 430m of index protection at 40bp.

- **Obviously, the investor can unwind the delta right away in the open market.**
- **Alternatively, the investor can ask for a "no-delta" upfront for the desired tranche**.
  - How can we compute the "no-delta" upfront for a tranche?
  - Adding to (if the client is buying prot.) or subtracting from (if the client is selling prot.) the tranche "with delta" upfront … the "cost of exiting the delta", taking into account the index bid-ask spread and the tranche delta:

$$Cost\ (\text{cents}) = \frac{\text{Full index bid - ask spread}}{2} \cdot \text{Index Duration} \cdot \text{Tranche Delta}$$

  - Example:
    - If the index was trading with a 0.5bp bid-offer and a 3 duration, the unwind cost would be 0.75c (of the index notional).
    - The delta of the 3-6% tranche was 4.3, thus the cost of unwinding the index would be 3.225c of the tranche notional.
    - As a consequence, the "no-delta" 3-6% tranche would pay an upfront of 0.625% - 3.225/10.000 = 0.59275%.

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Standard tranches

- Referring to the standard CDS indices and with constant attachment-detachment points.
- **Liquidly traded across IG and HY for both European and North American CDS indices**:

iTraxx Main

Series 9

Maturities	Tranches
Jun-15	0-3%
Jun-18	3-6%
	6-9%
	9-12%
	12-22%
	22-100%
Launched:	Mar-09

Series 19

Maturities	Tranches
Jun-16	0-3%
Jun-18	3-6%
	6-9%
	9-12%
	12-22%
	22-100%
Launched:	Mar-13

Series 21

Maturities	Tranches
Jun-17	0-3%
Jun-19	3-6%
	6-12%
	12-22%
Launched:	Mar-14

iTraxx Crossover - forthcoming

Series 22

Maturities	Tranches
Dec-17	0-5%
Dec-19	5-10%
	10-20%
	20-100%
Launched:	Sep-14

CDX IG

Series 9

Maturities	Tranches
Dec-14	0-3%
Dec-17	3-7%
	7-10%
	10-15%
	15-30%
	30-100%
Launched:	Sep-08

Series 19

Maturities	Tranches
Dec-15	0-3%
Dec-17	3-7%
Dec-19	7-15%
	15-100%
Launched:	Sep-12

Series 21

Maturities	Tranches
Dec-16	0-3%
Dec-18	3-7%
Dec-20	7-15%
	15-100%
Launched:	Sep-13

CDX HY

Series 8 / 9 / 10 / 15 / 17 / 19 21

Tranches
0-10%
10-15%
15-25%
25-35%
35-100%

Source: Citi Research

Bespoke tranches

- With **non-standard**
  - Underlying **portfolios** – of single name CDS.
  - **Attachment & detachment** points.
  - **Maturities**.

- Less liquid than standard tranches.

- Very common during the boom days of the synthetic tranche market (2004-8), especially among real money investors.
- Since then, hedge funds have been most active in “legacy bespokes”.
- Recently, new bespokes have been trading, mainly by hedge funds and focusing on junior tranches.

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Key events in the history of tranches

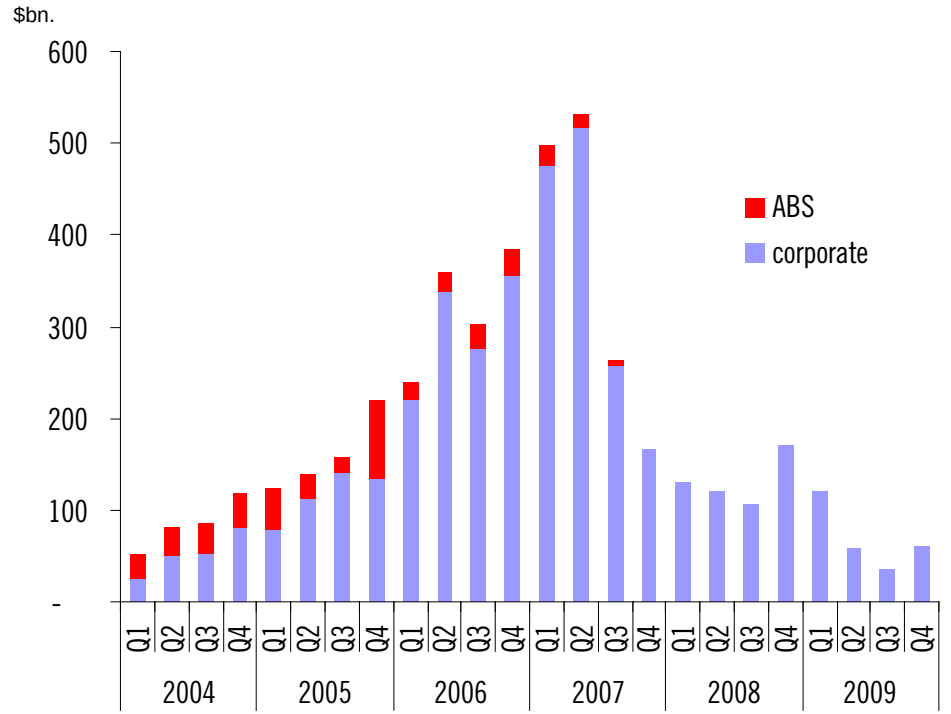
- **1999**
- First full capital structure CSOs (collateralised synthetic obligations).
- **2003**
- Rating agencies finalise rating approaches for CSOs
- First single tranche CSOs
- **2004**
- Standard index tranches launched in iTraxx & CDX
- **2005**
- Leverage super senior (LSS)
- CPPI products
- **2006**
- CPDOs
- **2007**
  - First unwinds and start of the crisis
- **2008/9**
  - CDX IG and iTraxx Series 9 launched
- **2012**
  - OTE distress and “London whale”
    - Impact on senior and equity tranche pricing
- **2013**
  - Liquidity in new series starts gathering pace
- **2014**
  - Xover tranches
  - The re-birth of the tranche market? We shall see …

Source: Citi Research,S&P, Moody’s, CreditFlux..

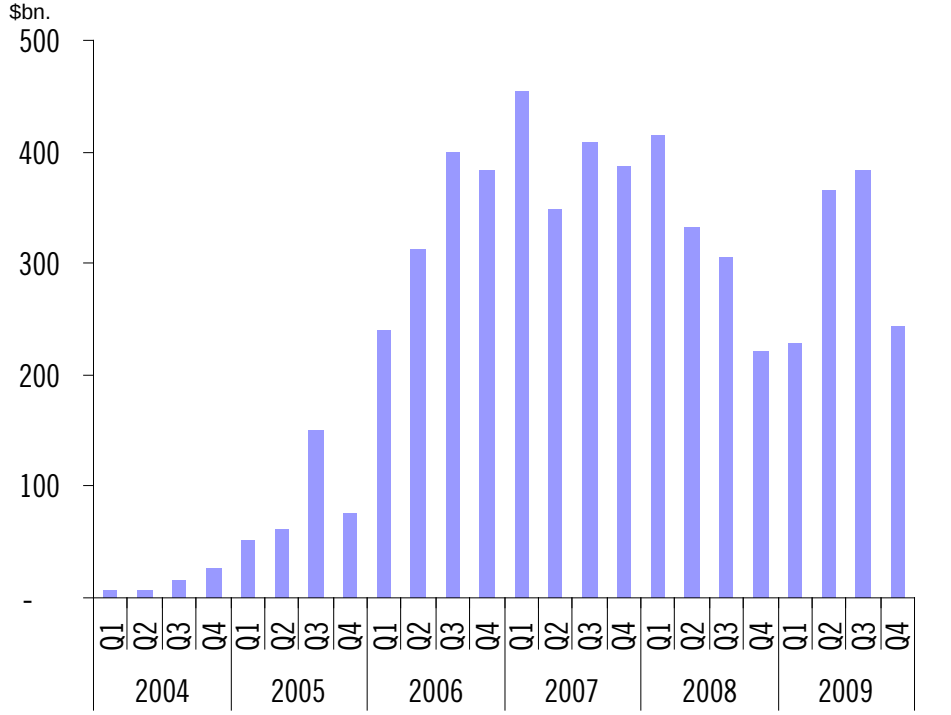
Pre-financial crisis: 2004-2007

- **Issuance of bespoke tranches** ("CSOs" – Collateralised Synthetic Obligations) **grew aggressively from 2004 to mid-2007**.
  - First wake-up call: Bear Stearns structured hedge fund losses in July 2007.
- **The standard tranche market was primarily launched in order for dealers to be able to hedge their bespoke positions**.
  - Volumes in synthetic tranches remained high post 2007, predominantly dominated by hedge funds and sophisticated real money investors.

Bespoke tranche issuance



Standard index tranche volumes

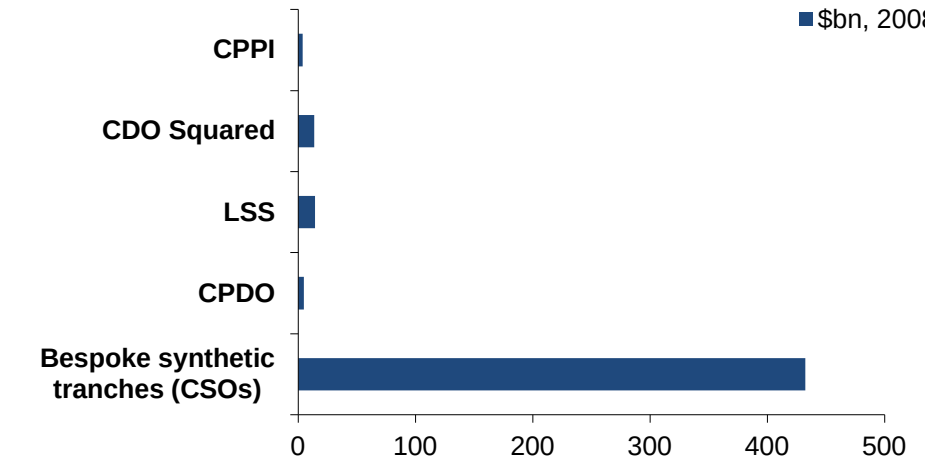


Source: Citi Research

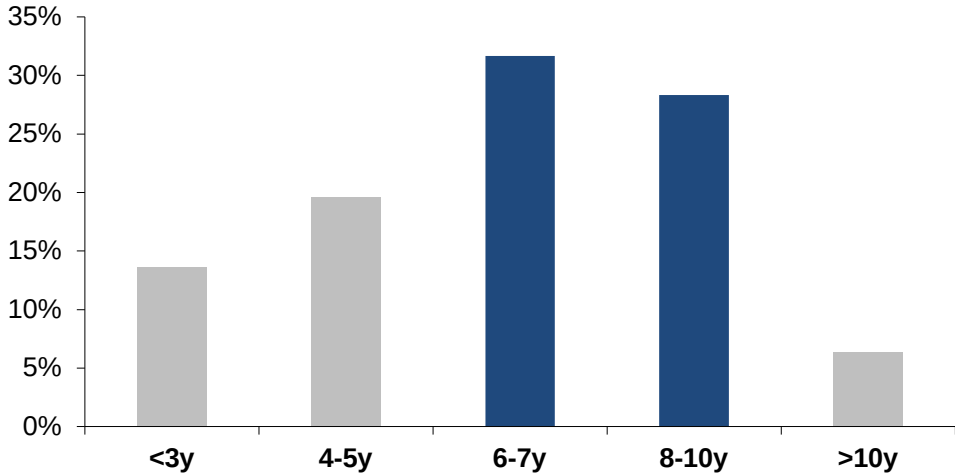
Pre-financial crisis: 2004-2007

- **Banks start creating Cash CDOs to reduce their credit exposure**
- **Investment banks create full capital structure synthetic CDOs to sell to clients**
  - To create a cash CDO you have to put together a portfolio of bonds, which can take a substantial amount of time
  - Doing it with CDS takes very little, causing synthetic CDOs (CSOs) to quickly become popular
- **Investment banks create single tranche synthetic CDOs**
  - No need to place the full capital structure
- **Investment banks need to hedge the single tranche synthetic CDO tranches they sell:**
  - They can hedge the "default" risk with CDS or indices but…
  - How do they hedge the "correlation" exposure?
  - Standard tranches on CDS indices are born, i.e. synthetic tranches with an underlying standard CDS portfolio

Size of the rated structured credit market



Maturity distribution of CSOs issued 2006-08



Source: Citi Research, S&P, Moody's, CreditFlux.

Pre-financial crisis: 2004-2007

- **The structured credit products market grew rapidly between 2003 and 2007.**
  - Investor search for extra spread in a low spread environment.
  - Increased comfort with derivative products, product innovation in derivative structuring, financial modelling advances and rating agency participation in an environment of low perceived default risk.
- **A wide variety of investors around the world participated in this market, including insurance companies, banks, brokers, hedge funds and asset managers.**
  - As a consequence, many different structures were created to meet the needs of this diverse investor base.

  - **Mezzanine tranches were the most popular** among CSO structures and were mostly held as static hold-to-maturity investments.
  - **Equity tranches were mostly held by hedge funds** which actively managed and hedged them to gain exposure to secondary risks such as spread convexity, correlation and capital structure relative value as well as “Jump-to-Default”.
  - **In super senior tranches, leverage was generally applied** in order to make them more attractive (Leverage Super Senior).

  - **Most structures suffered significantly during the credit sell-off**
  - High mark-to-market volatility (due to their leverage, i.e. delta to the index), significant ratings downgrades and principal losses due to defaults.
  - The largest determinant of tranche performance during the crisis turned out to be portfolio quality rather than position in the capital structure (i.e. tranche seniority or leverage).

2008-2012

- **The standardised CDS index tranche market originally arose from a need of correlation desks to hedge out their exposure from selling synthetic bespoke tranches (CSOs)**.
  - When the bespoke market shut down at the end of 2007 the standardised tranche market no longer rolled into the new series of the CDS indices.
  - However, a need to hedge the existing bespoke tranches still existed and so liquidity continued in the tranches that had maturities and compositions best matched to the existing bespoke tranches.
  - These tranches were the iTraxx Main Series 9 and CDX IG Series 9 series which, until recently, were the only liquid CDS tranche products.
  - The liquidity on standard tranches in new Series started gathering pace in 2013, especially in the US.

- **What traded? Who traded?**
  - **Real money investors** were active **unwinding** CSOs entered into during previous years.
  - **Hedge funds were actively involved in "legacy bespokes" coming out of real money books** – generally at relatively "distressed prices".
  - **Dealers were keen to provide liquidity on the standard tranches** to be able to hedge their exposures.
    - Hedge funds and sophisticated real money investors were active in this market, mostly selling mezz protection which was trading at wide spreads given mezz CSO unwinds.
    - Consolidation among dealers: some sell their entire books to other banks / hedge funds.

2013-2014

- **Large demand from hedge funds for equity tranches**
  - Taking exposure to levered default risk, minimising the exposure to market risk.
  - Probably the best trade during this period.
- **2014 sees a pick-up in the demand for mezzanine tranches**
  - From hedge funds switching from stretched equity tranches.
  - From sophisticated real money investors looking for high spread instruments with default subordination.
- **Dealers initially have a tough time to find sellers of super senior protection**
  - Although they're appearing…

- **Tranche liquidity in new Series starts gathering pace**
- **Xover tranches launched in September 2014**
- **Will we see the tranche market coming back in force?**
  - The tranche market is a very pro-cyclical one: little traction when spreads are wide & the only place to go when they are tight.
  - We need investors to be more bullish and spreads to be tighter for the market to take off.
  - Is that coming?

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- Tranche risk exposures
- Delta-hedging
- Popular strategies
- Pricing
- Other topics

Resources at Citi

- **Credit derivatives research**
  - Abel Elizalde – Europe
  - Anindya Basu – US
- **Analytics & Market snapshot on Citi Velocity**
  - Credit tranches market snapshot
  - Credit tranches daily analytics
- **Comprehensive data available on Citi Velocity**
  - Tranche upfronts, spreads
  - Historical correlations
- **Forthcoming: Online pricing tool on Citi Velocity**
  - Ability to analyse trade ideas.
  - MtM scenarios and cash flow analysis.

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Credit Products Strategy

Citi Research

iTraxx Main Series 9 Tranche Report

See Appendix A-1 for Analyst Certification, Important Disclosures and non-US research

Data as of COB 15 Apr 14

iTraxx Main Series 19 Tranche Report

Tenor: 7y Jun-15

	Upfront	Flat spread	Spread	Change (Upfront / flat spread) 1w	1m	3m	Coupon	Delta	Spread / Delta	RA	B. Corr.	Exp. Loss Level	Exp. Loss Ratio
0-3%	-0.10%	491	491	0.84%	-1.55%	-1.68%	5.00%	21.4	23	1.17	46.4%	5.8%	74.5%
3-6%	-5.59%	31	35	3	-28	-23	5.00%	2.9	11	1.20	56.5%	0.4%	5.5%
6-9%	-3.38%	16	19	4	-7	-10	3.00%	1.5	11	1.20	62.6%	0.2%	2.9%
9-12%	-1.07%	10	11	2	-7	-6	1.00%	0.9	12	1.20	67.3%	0.1%	1.8%
12-22%	-1.11%	7	8	1.7	-3.6	-2.2	1.00%	0.6	12	1.20	77.4%	0.1%	4.2%
22-100%	-0.27%	3	3	0.2	-2.0	-1.4	0.25%	0.2	17	1.20		0.0%	11.1%
Ref	-1.82%	18		3.1	-7.0	-6.7	1.70%	1.0	18	1.20		0.2%	

Tenor: 10y Jun-18

	Upfront	Flat spread	Spread	Change (Upfront / flat spread) 1w	1m	3m	Coupon	Delta	Spread / Delta	RA	B. Corr.	Exp. Loss Level	Exp. Loss Ratio
0-3%	18.31%	1040	1022	1.15%	-3.70%	-4.08%	5.00%	8.5	122	3.51	55.9%	35.9%	38.4%
3-6%	-7.18%	317	321	17	-51	-51	5.00%	4.8	66	4.00	63.1%	12.8%	13.8%
6-9%	-4.68%	184	186	8	-36	-26	3.00%	3.0	61	4.09	68.2%	7.6%	8.1%
9-12%	0.71%	117	117	7	-21	-22	1.00%	2.1	57	4.13	72.8%	4.8%	5.2%
12-22%	-1.51%	63	64	4.4	-11.3	-5.5	1.00%	1.2	53	4.17	85.2%	2.7%	9.5%
22-100%	-0.14%	22	22	0.8	-4.7	-3.4	0.25%	0.4	57	4.15		0.9%	25.1%
Ref	-4.44%	67		2.8	-10.2	-7.8	1.75%	1.0	67	4.11		2.8%	

CitiVELOCITY

CREDIT COMMODITIES SECU

DATA & ANALYTICS
Analytics Overview
Charting 2.0
Curve
Credit Flow
Credit Heatmap
Asset Allocation
Yield Book Calculator Select
Bond Scatter Graph
Portfolio Intelligence
Sentiment Monitor 2.0
Options Pricing Tool

since: 15-Oct-13

10y - index spread & equity tranche correlation
LHS: index spread (bp). RHS: equity tranche correlation (%).
Data since: 15-Oct-13

Agenda

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- Tranche risk exposures
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- Pricing
- Other topics

Let’s get the intuition first and then we do the numbers

- In a very simplified way, **the main risks affecting tranches are**:
  - **The absolute risk in the portfolio/index – the portfolio spread or expected loss**
    - This is the expected loss (due to defaults and losses on default) of the portfolio.
    - It is relevant in tranche pricing because it gives an indication of how valuable subordination is.
      - For a portfolio that is expected to lose 10%, 3% of subordination may not be very appealing to investors, but 3% may be sufficient for a portfolio expected to lose only 1%.
    - Expected loss = spread x duration (risky annuity)
      - E.g. for iTraxx Main S21 5y trading at 70bp with a risky annuity of 4.5 = 3.1% expected loss.
  - **The default correlation among the names in the portfolio**.
    - This is the “expected **default contagion**” among portfolio entities.
    - Portfolios with low correlation will have risk concentrated in equity tranches, whereas portfolios with higher correlations will begin to show more risk in senior tranches.
- The “correlation” point is the bit where new investors in this market most struggle with … so let’s look at it in a bit more detail.
- All clear on the importance of portfolio spread / expected losses?

Agenda

Splitting risks: Market/systemic vs. default/idiosyncratic risks

Portfolio correlation and impact on tranche risk - intuition

What level of correlation has the market historically priced in?

Which tranches are equity and which tranches are senior?

Example I – Simple (just a few numbers, not a single chart)

- We have an index (i.e. portfolio) on which there are two tranches, a 0-10% equity tranche and a 10-100% senior tranche.
- The expected loss of the index is 10%.

Scenario A – Low correlation

- 50% probability of 5% loss to portfolio
- 50% probability of 15% loss to portfolio

- **Index expected loss** = 50% × 5% + 50% × 15% = **10%**
- **Equity tranche expected loss**:

  50% × (5-0)/10 + 50% × 100% = **75%**
- **Senior tranche expected loss**:

  50% × 0% + 50% × (15-10)/90 = **2.8%**

- **Equity tranche is much riskier than senior**

Scenario B – High correlation

- 90% probability of 0% loss to portfolio
- 10% probability of 100% loss to portfolio

- **Index expected loss** = 90% × 0% + 10% × 100% = **10%**
- **Equity tranche expected loss**:

  90% × 0% + 10% × 100%= **10%**
- **Senior tranche expected loss**:

  90% × 0% + 10% × 100% = **10%**

- **Equity and senior tranches are equally risky**

- In both scenarios the index expected loss is 10% (i.e. “absolute” portfolio risk), but these losses are distributed in very differently.
- **For the same portfolio expected loss: Are equity tranches better off in a low or high correlation environment? And seniors?**

Recapitulating

- **Senior tranches provide investors with exposure to market-wide systemic risk**, i.e. events which involve high correlation.
  - Example of an event which will increase the correlation of a portfolio?
  - **Equity tranches provide exposure to idiosyncratic (company-specific) risk**, i.e. events which involve low correlation.
  - Example of an event which will reduce the correlation of a portfolio?

Long risk an equity tranche

Other things equal:

- Do you benefit from the portfolio spread / expected loss going:
- Up?
- Down?

- Do you benefit from the portfolio correlation going:
- Up?
- Down?

Long risk a senior tranche

Other things equal:

- Do you benefit from the portfolio spread / expected loss going:
- Up?
- Down?

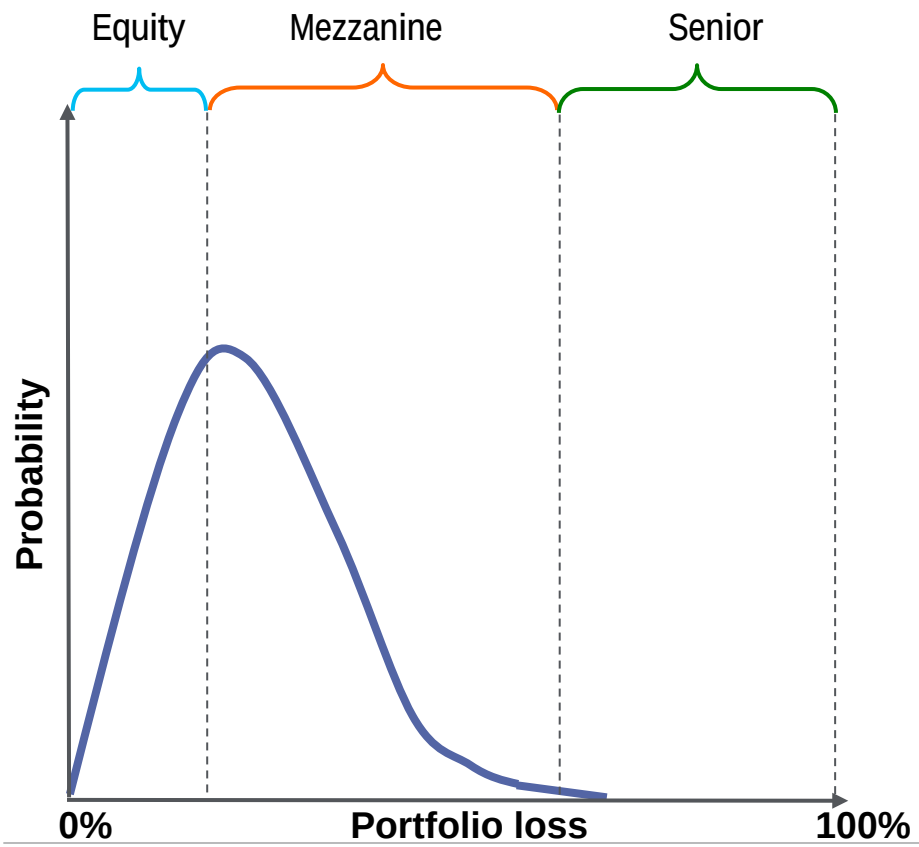
- Do you benefit from the portfolio correlation going:
- Up?
- Down?

Example II – A bit more involved (some charts shown)

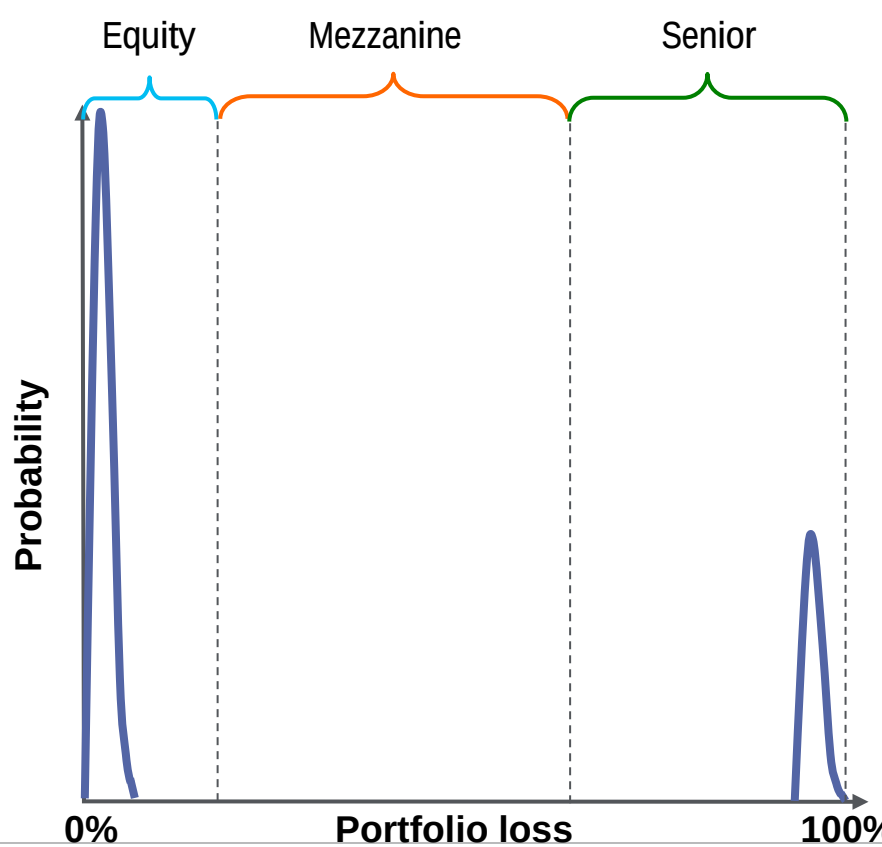
- **Low correlation**:
  - Default of one name doesn't affect the default probability of any other name.
  - Likely have a few defaults, but it'll be unlikely to have a lot.
- **Perfectly correlated**:
  - The default of one name triggers the default of all the rest.
  - Either we have no defaults, or the whole index defaults.

Probability of portfolio losses for two extreme correlation levels

Low correlation



High correlation



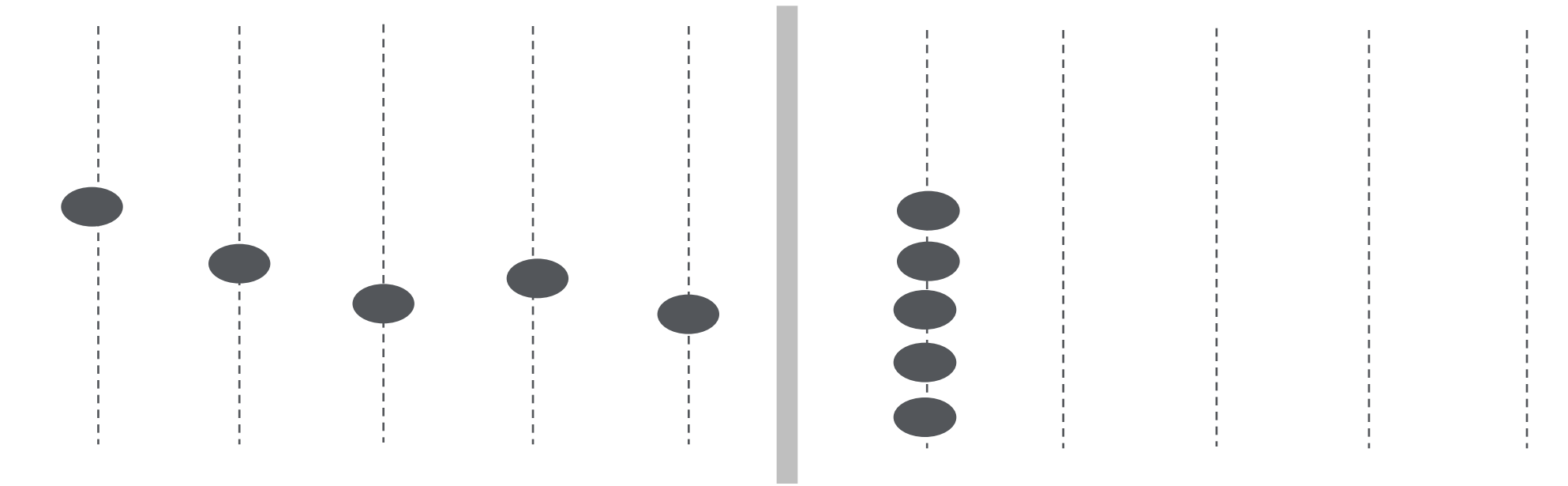
Source: Citi Research

Correlation intuition: Slides of last resort (I)

- You are a General (Portfolio Manager). You are in charge of five people whom you need to transport from one place to another, separated by a cratered field.
- The field consists of five “lanes” or “passages” through which the people can travel. There are exactly five holes in the field. You do not know how the holes are distributed among the lanes.
- They can either be: “**Un-correlated**”: one hole on each line (left chart) or “**Correlated**”: all holes on one lane (right chart)
- **You don’t know how the holes are “distributed”, you just know there are five holes.**

Low correlation field

High correlation field



- **Total risk** (number of holes: portfolio absolute risk or spread / expected loss) **is the same, but risk distribution (correlation) is not**.

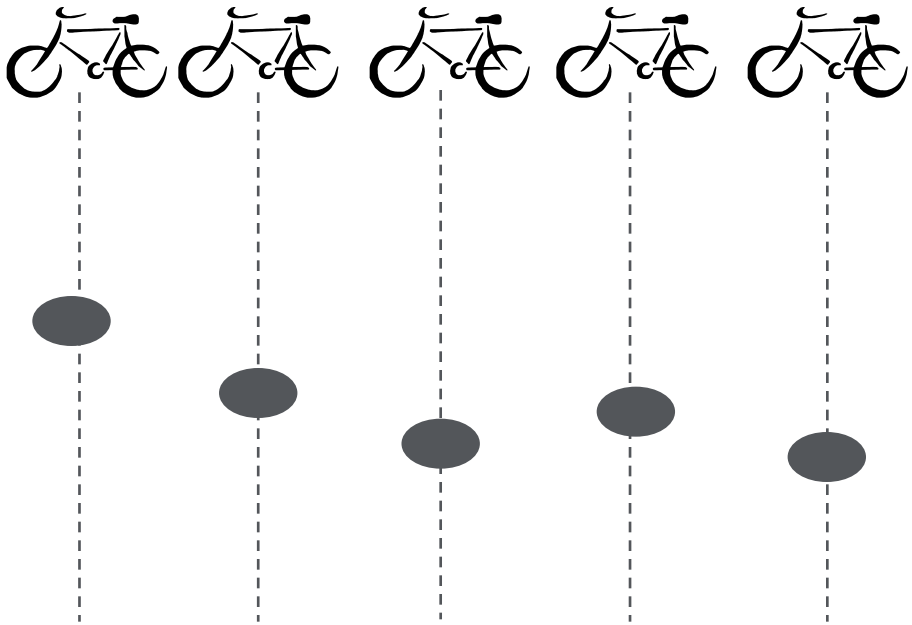
Source: Citi Research

Correlation intuition: Slides of last resort (II)

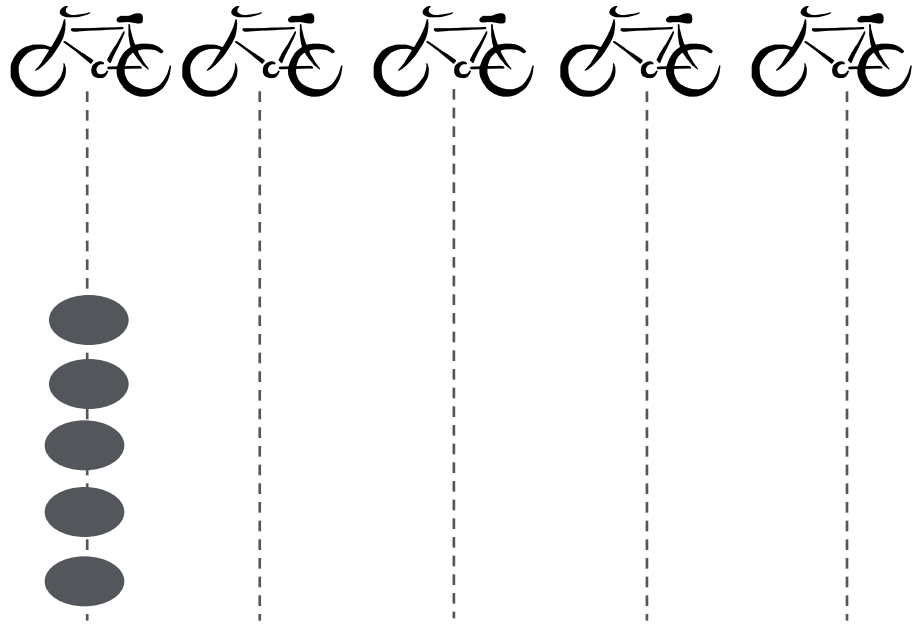
- Your budget is limited and you have to make a choice:
  - **Sell equity prot**. – Get a **bicycle** for each person and place each of them on a different line. A bicycle is "wiped-out" with a hole.
  - **Sell senior prot**. – Get a **truck** and transport all people together through one line. It can withstand four holes, it's "wiped-out" with the fifth.

Equity tranche: Bicycle – Better off in a high correlation environment

Low correlation field



High correlation field



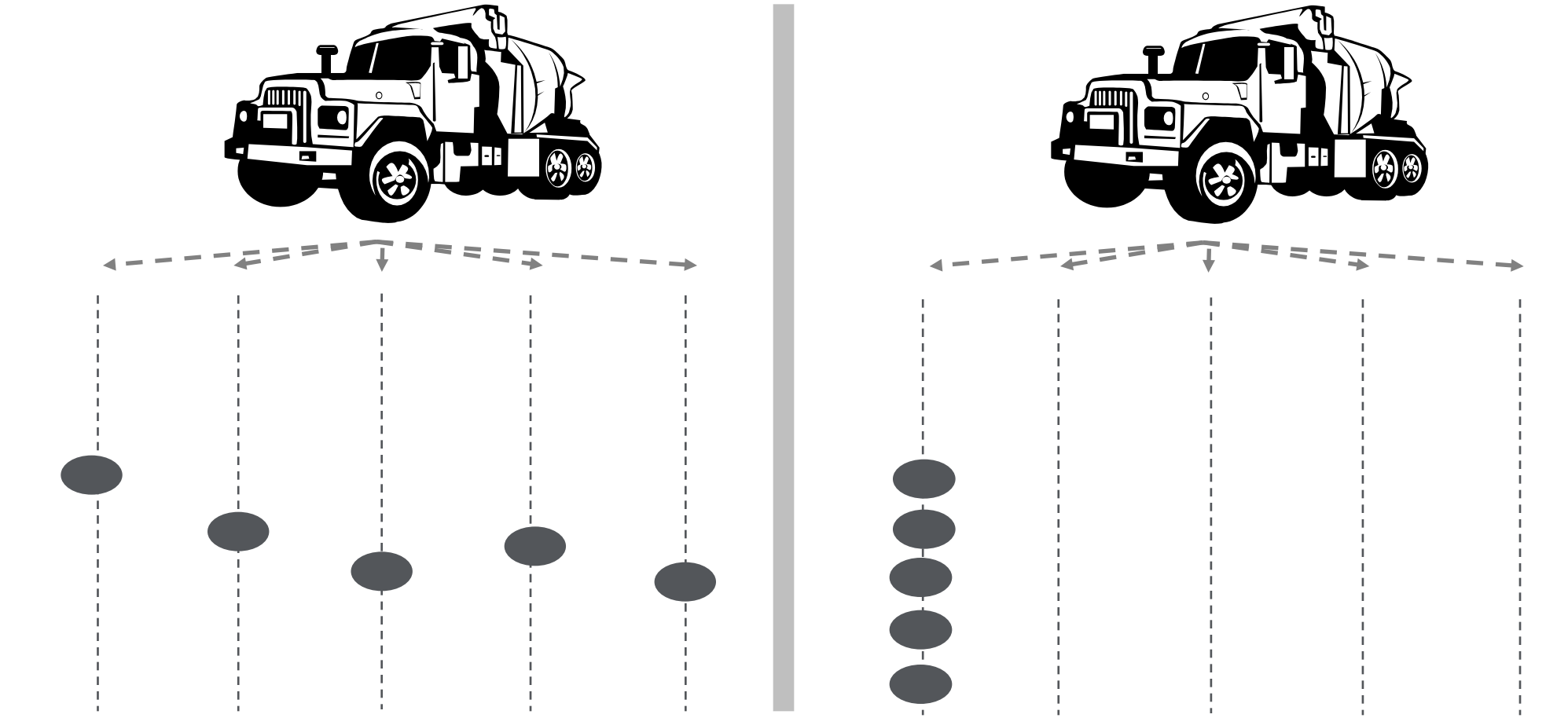
- **For equity tranches** (i.e. each soldier on a bicycle, each on a different line), **high correlation / low idiosyncratic risk is preferred.**

Source: Citi Research

Correlation intuition: Slides of last resort (III)

- **For senior tranches** (i.e. get a truck, put all people in it and go through one line), **low correlation / low systemic risk is preferred**.

Senior tranche: Truck – Better off in a low correlation environment



Source: Citi Research

Correlation and the underlying portfolio / index

- Many people would initially think that higher correlation among the names on an index make the absolute index risk higher.
  - That is not the case.
  - **Treat absolute risk (i.e. spread / expected loss) and correlation independently**.
  - We will see in a chart next, showing historical spreads and index correlations, how their correlation can be positive or negative.

- **Default correlation does not affect the total expected losses, and as a consequence it does not affect the index itself …**

  Clear?

  - Example: Imagine a CDS index of 125 equally weighted credits, ALL trading at 100bp.

    What is the index theoretical spread if …

    - ... the names are very correlated?
    - ... the names are not correlated?

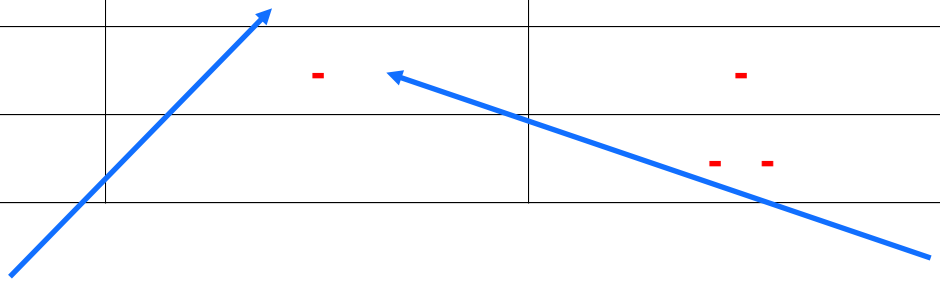
    100bp in both cases.

- **The "correlation" level of the single names does not impact the index spread or expected loss**.
- It will impact the distribution of potential losses on the index, as we have seen, but not the index expected loss.

Make sure you understand this slide

- Main risk factors affecting tranches (and index, i.e. 0-100% tranche):
  - Index spreads / expected losses (a combination of default probabilities (PDs) and recovery rates)
  - Correlation
  - Default of one underlying company ("JtD" – Jump-to-Default)
  - Passage of time ("time value")
- The table below shows the MtM (from the point of view of a protection seller) of different tranches with respect to the above factors (assuming we "increase" them: spreads increase, correlation increases, a default happens and time goes by).

	Spreads (i.e. PDs and expected recoveries) of companies in the index	**Correlation** (of companies credit quality)	**Default** of one company	**Time** (passage of time)
Equity Tranche	- - -	+	- - - - -	+ + +
Senior Tranche	-	-	-	+
Index	- -		- -	+ +



- **We say that a (long risk) junior tranche is long correlation (makes money if correlation goes up) and a senior tranche is short correlation.**

Source: Citi Research

Agenda

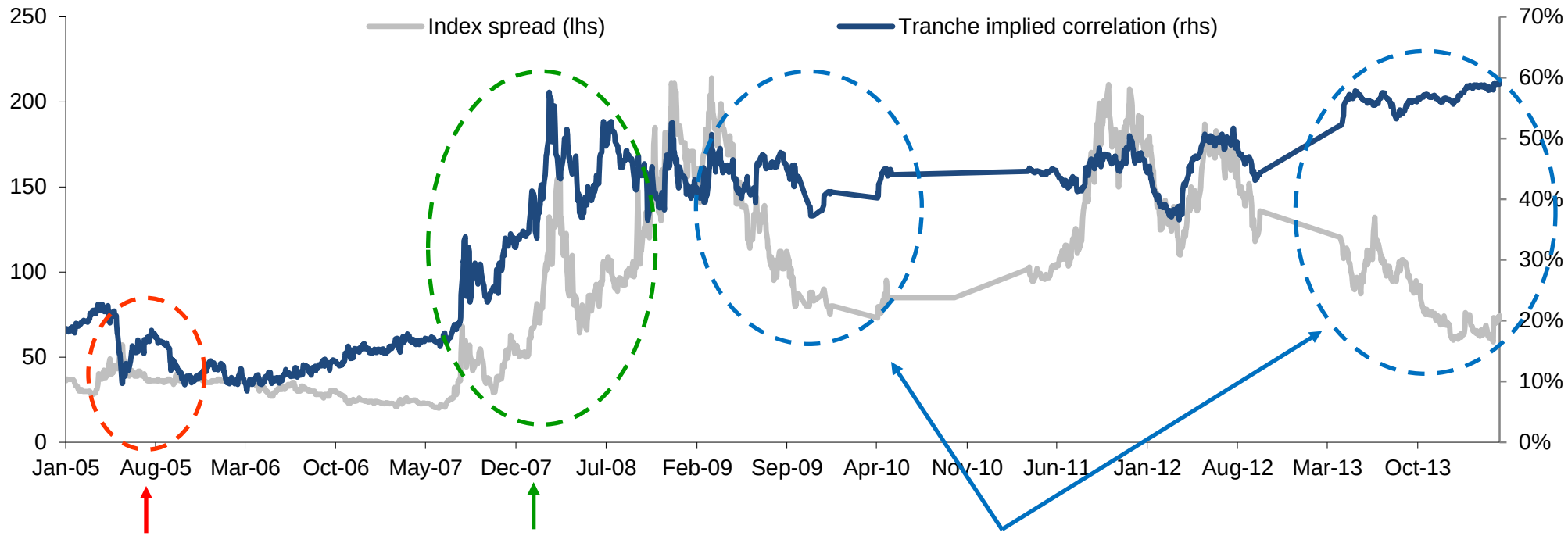
- Splitting risks: Market/systemic vs. default/idiosyncratic risks
- Portfolio correlation and impact on tranche risk - intuition
- **What level of correlation has the market historically priced in?**
- Which tranches are equity and which tranches are senior?

What level of correlation has the market historically priced in?

- From tranche prices we can "derive" the correlation that market participants are assuming (more on this later).

Historical implied correlations and index spreads – iTraxx Main 5y On-the- Run

LHS: 5y on-the-run index spread, in bp. RHS: implied correlation by 5y on-the-run equity tranches, in %.



GM & Ford downgrades

Spreads widen and correlation falls ("an IG default is possible")

This event was called the "correlation crisis" back then.

Financial crisis

Spreads and correlations increase

Spreads tighten but correlation stays high / increases

i) Demand to buy senior protection as a tail hedge

ii) Demand to sell equity tranche protection to take levered default exposure

- **What is the "fundamental" correlation level on an IG portfolio: 15% like pre-07 or 50-60% like post-07?**

Source: Citi Research

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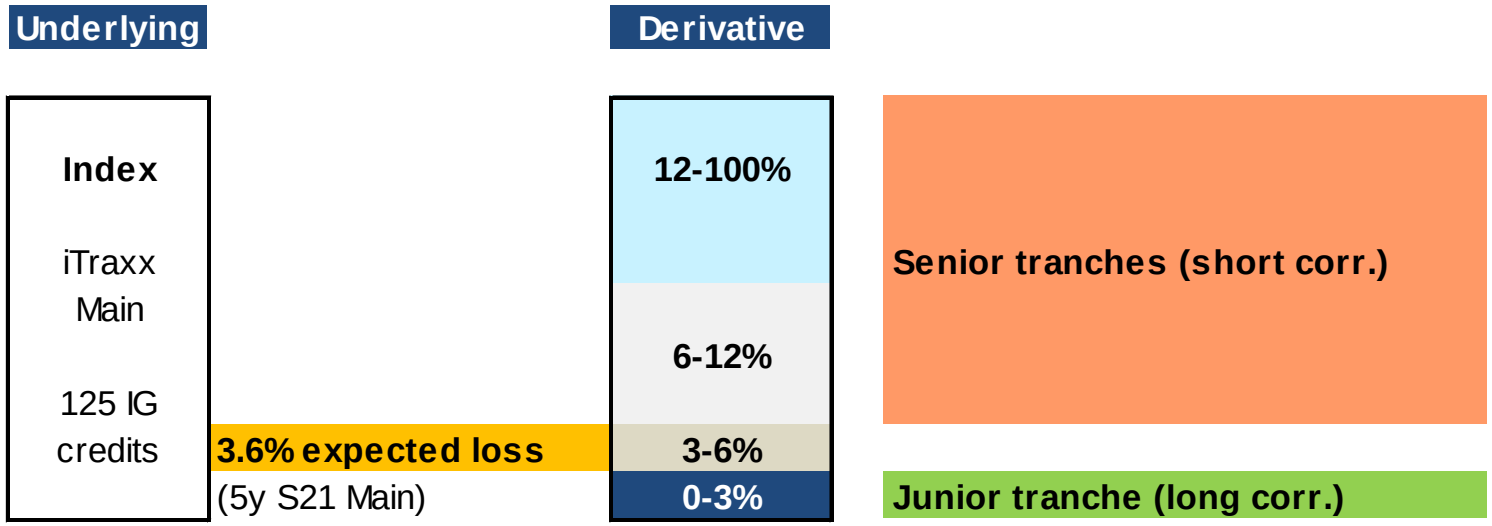
- **Which tranches are equity and which tranches are senior?**

What's "junior"? What's "senior"? What about "mezz"?

- **We say that a (long risk) junior tranche is long correlation (makes money if correlation goes up) and a senior tranche is short correlation.**
- We'll go through this in a bit more detail later, but as a rule of thumb:
  - Junior tranches (long correlation): tranches below the index expected loss
  - Senior tranches (short correlation): tranches above the index expected loss
  - Tranches close to the expected losses tend to be quite insensitive to correlation movements
  - Thus, **the "pivot" point for correlation exposure tends to be the index expected loss**.
  - Expected loss = spread x duration



Source: Citi Research

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- Tranche risk exposures
  - **Delta**
  - Jump-to-default
  - Spread dispersion
  - Implied Correlation
  - Time Value
  - Summary of risk exposures

Delta or Leverage

- The delta or leverage of a tranche provides an indication of **how many times "riskier" a tranche is, compared to its underlying index, with respect to spread movements**.
  - Tells you about the **"directional" (i.e. spread) exposure of a tranche** – i.e. leverage.
  - Index position which generates a similar spread exposure as the tranche (in MtM terms) for small spread movements.
  - Example – If you sell 100m protection of a S21 Jun-19 3-6% with a 4.4x delta …

    you would need to buy 440m of index protection for the MtM of your entire position to be neutral to small spread changes.

- If the index tightens 1bp – How much money would you make in 3-6% Jun-19 tranche with a 4.4x delta?
  - How much money would you make in and index long?

    1bp x index duration = 1bp x 4.9 = 4.9 cents
  - Multiply that by the option delta

    4.9 x 4.4 = 21.56 cents

iTraxx Main S21 Tranches

As of 4-Apr-14.

ITRAXX21 06/17 (40 Mid)		Delta	SECBid SECAsk
0-3	15.625/16.625	10.7X	634 671
3-6	0.625/1.625	4.3X	120 151
6-12	60/70	2.1X	60 70
12-100	13.625/16.625	0.5X	13.62 16.62
ITRAXX21 06/19 (71 Mid)		Delta	SECBid SECAsk
0-3	33.625/34.875	6.6X	909 947
3-6	9.625/10.875	4.4X	299 326
6-12	161/176	2.6X	161 176
12-100	32.625/34.375	0.55X	32.62 34.37

Source: Bloomberg, Citi

Delta or Leverage

- Calculation: **If** (only) **index spreads move** (but only a little bit, e.g. 1bp), **how much the MtM of a tranche moves compared to the index?**
  - Take the current tranche and index prices.
  - Assume the spreads of all the underlying single name CDS change (e.g. +/- 1bp additively or + / - 1% multiplicatively).
  - Compute the MtM of each tranche and index.
  - Delta or Leverage = Tranche MtM / Index MtM.

- Some “problems” of “deltas”
  - **They only work for SMALL spread movements applied to ALL credits**
    - What if the spread movement is large? CONVEXITY (more on this later)
    - What if the spread movement is not uniform across credits? DISPERSION (more on this later)
  - They are model dependent (that’s why the dealers fix it every day).

Delta or Leverage

- **Imagine we sell protection on an equity tranche against its delta**
  - E.g. Sell 10m Main S21 Jun-17 0-3% tranche protection and buy 107m (= 10 x 10.7) index protection.
- **We would be hedged against small movements in spreads**, but we would still have **residual exposure** to:
  - **Defaults**
    - Assume a 40% recovery rate. One default
      - Equity tranche cash default settlement: 16% x 10m = 1.6m loss
      - Index cash default settlement: 0.48% x 107m = 0.51m gain

      A long risk equity tranche vs. delta loses money from an instantaneous default.
  - **Large spreads movements**
  - **Not uniform spread movements across the single names in the index**
    - Example: the 5 widest names in the index widen and the 30 tightest names tighten in such a way that the index spread doesn't move. Does the trade make or lose money?
  - **Time passing by** – Does the trade make or lose money?
  - **Movements in implied correlation** – Does the trade make or lose money?

  - We'll look at this in more detail in a later section.

Delta or Leverage

- How would you expect the delta of a tranche to change with:
  - Tighter index spreads?
  - Lower default correlation in the underlying?
  - A single name distress story suddenly emerging?
  - More dispersion in the underlying portfolio?
  - Shorter time to maturity?

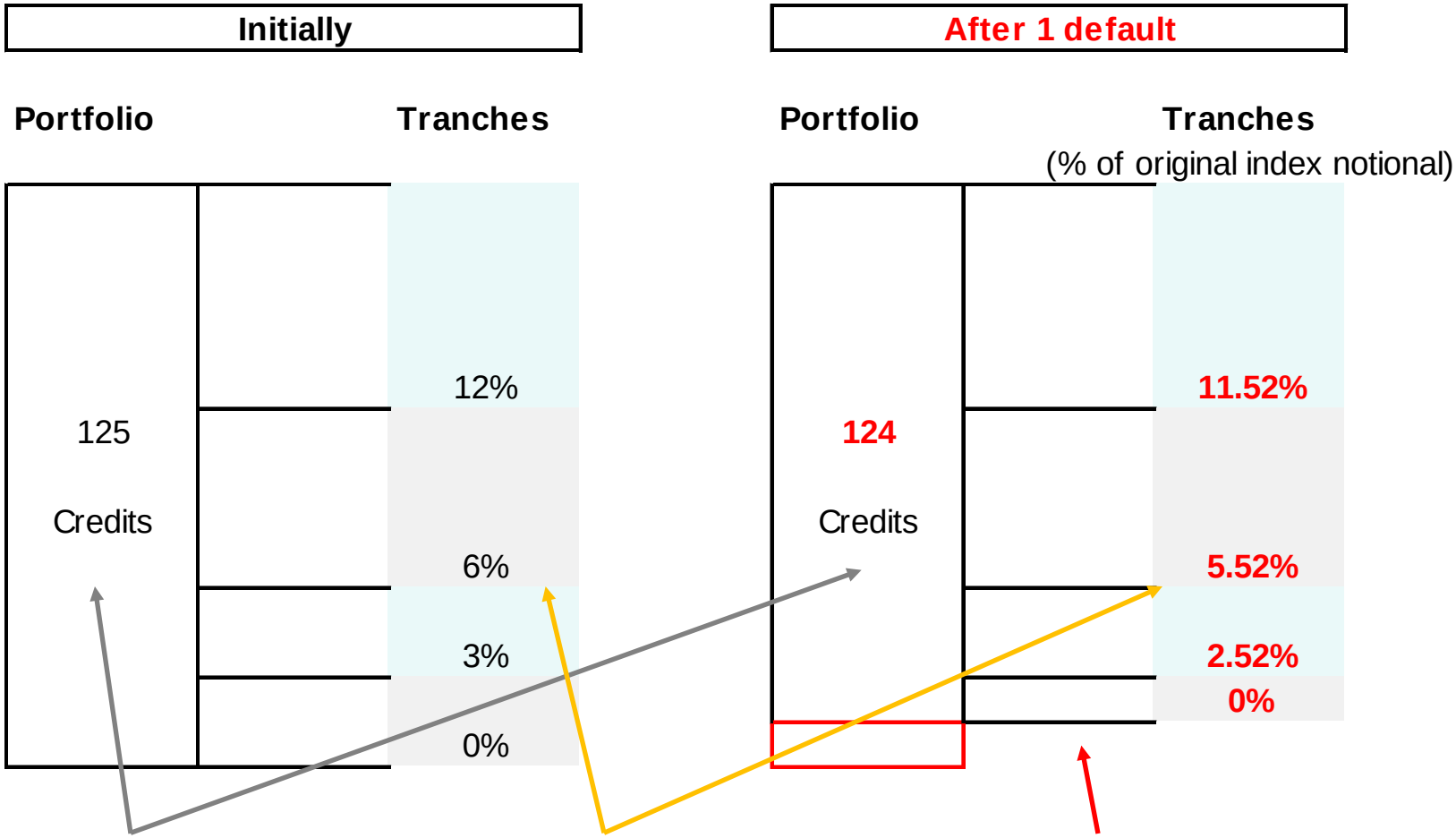
Agenda

- Tranche risk exposures
  - Delta
  - **Jump-to-default**
  - Spread dispersion
  - Implied correlation
  - Time Value
  - Summary of risk exposures

Jump-to-Default (JtD)

- Imagine there is an instantaneous default in iTraxx Main S21 with a 40% recovery (0.48% index loss; 16% equity loss):

Jump-to-default: Total P&L after one instantaneous default



P&L impact:

Different portfolio: Riskier? Less risky? + **Lower attachment / detachment points** + **Equity tranche suffers direct losses**

Source: Citi Research

Jump-to-Default (JtD)

- Definition: **P&L impact, on a tranche or index position, of an instantaneous default in one of the index constituents**
- **JtD has two components**:
  - **Losses due to lower subordination**
    - Equity suffers a settlement loss and becomes thinner: With 40% recovery, loss = 0.48% / 3% width = 16%.
    - Non-equity tranches suffer a MtM loss due to the reduction in subordination: 0.48% with 40% recovery.
  - **Riskiness of the portfolio changes depending on which name defaults**
    - If the riskiest/less risky name defaults, the remaining portfolio becomes less/more risky.

iTraxx Main S21 Tranches – JtD widest credit

As of 17-Apr-14. As % of tranche notional. From a protection seller's point of view.

Tranche	Jun-17	Jun-19
0-3%	-14%	-12%
3-6%	-0.8%	-1.5%
6-12%	-0.19%	-0.42%
12-100%	-0.01%	-0.02%
Index	**-0.48%**	**-0.50%**

Widest credit: Glencore 5y CDS @ 175bp

Why less than 16% for equity?

Why does it go down with tenor?

Why is the JtD less negative for the widest credit?

JtD: Widest vs. Tightest credit

As of 17-Apr-14. As % of tranche notional. From a protection seller's point of view.

Tranche	Widest	Tightest
0-3%	-11.95%	-12.32%
3-6%	-1.51%	-1.79%
6-12%	-0.42%	-0.59%
12-100%	-0.02%	-0.05%
Index	**-0.45%**	**-0.51%**
Jun-19	GLEINT	NESTLE

Widest credit: Glencore 5y CDS @ 175bp
Tightest credit: Nestle 5y CDS @ 25bp

Source: Citi Research

Jump-to-Default (JtD)

iTraxx Main S21 Equity tranches – As of 17-Apr-14

		Upfront	Flat spread	Coupon	Delta
Tenor: 3y	Jun-17	**16%**	674	1%	11.0
Tenor: 5y	Jun-19	**34%**	941	1%	6.5

iTraxx Main S21 Tranches – JtD widest credit

As of 17-Apr-14. As % of tranche notional. From a protection seller's point of view.

Tranche	Jun-17	Jun-19
0-3%	-14%	-12%

► Why less than 16% for equity?

Because the default loss is priced in already to an extent.

Take the Jun-19 equity, trading at 34%.

If you sell protection there, the maximum amount you can lose is 100% - 34% = 66%; and that's if you have 7 defaults with 40% recovery rate.

Thus, even though the cash you have to pay for each default is 16%, your MtM is not 16% because you use the initial upfront to pay for them.

► Why does it go down with tenor?

Because upfronts are higher for longer dated tenors.

With seven instantaneous defaults, you would lose:

100% - 16% = 84% in the Jun-17

100% - 34% = 66% in the Jun-19

Thus, one default will generate higher MtM on the short dated tenor (although the cash payment will be the same across tenors).

JtD: Widest vs. Tightest credit

As of 17-Apr-14. As % of tranche notional. From a protection seller's point of view.

Tranche	Widest	Tightest
0-3%	-11.95%	-12.32%

► Why this difference?

If you sell protection, you would prefer the widest credit to default, because the remaining portfolio becomes less risky.

If the tightest credit defaults, the remaining portfolio becomes riskier.

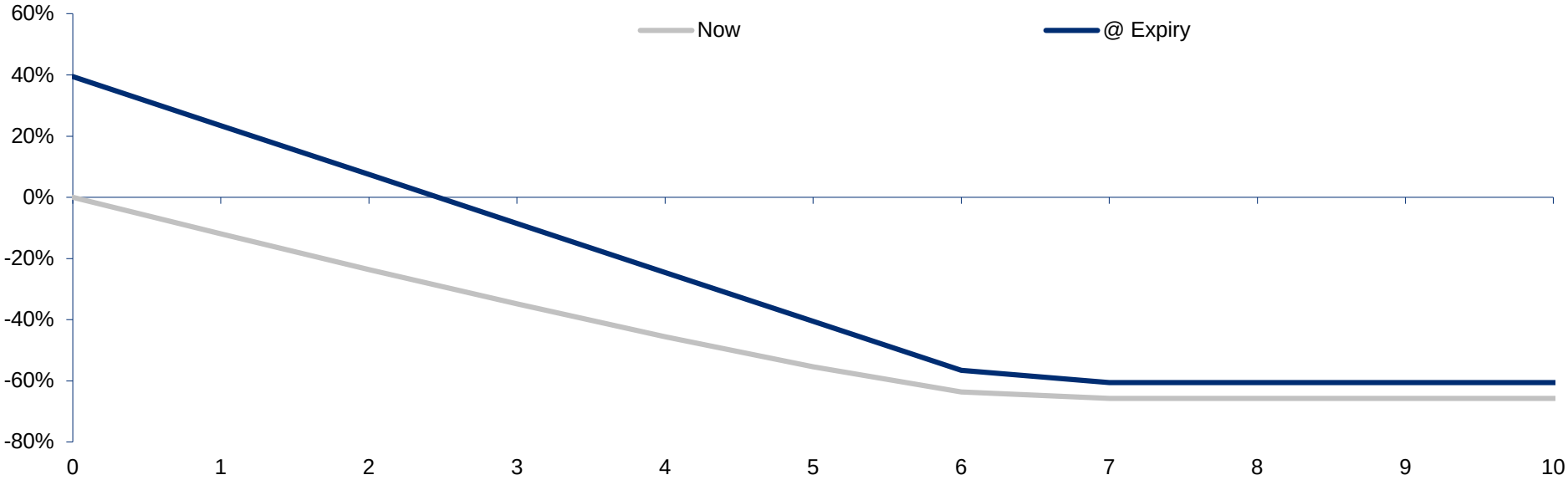
Source: Citi Research

Jump-to-Default (JtD)

- Assume you sell Jun-19 **Equity (0-3%)** protection at 34% upfront (+100bp coupon) on 17 April 2014.

P&L vs. cumulative defaults: Today and at Expiry

As of 17-Apr-14. As % of tranche notional. From a protection seller's point of view.



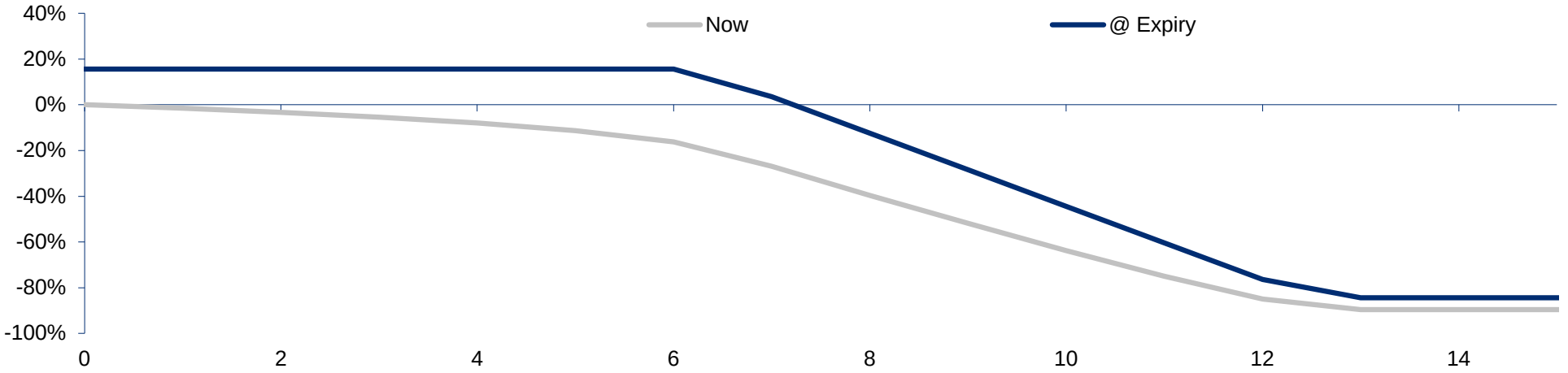
- **Defaults today**: If the tranche is wiped out, you lose 100% minus the upfront you received (34%), i.e. 66%.
- **Defaults at expiry**: You collect coupons of 1% per year for 5.25 years (5.25%) which, together with the initial upfront received add up to 39.25%. With the 39.25% you can afford to pay two defaults with 40% recovery (16% loss each) if they happen just before expiry. With seven or more defaults, the equity tranche is wiped out and the total loss is 100% - 39.25% = 60.75%.
- Thus, **equity tranches are very sensitive to the timing of defaults**: As defaults happen, the outstanding notional decreases and so does the carry received going forward. This is **especially** the case **for** equity tranches trading with **high coupons** (e.g. 5% for Main S9).

Source: Citi Research

Jump-to-Default (JtD)

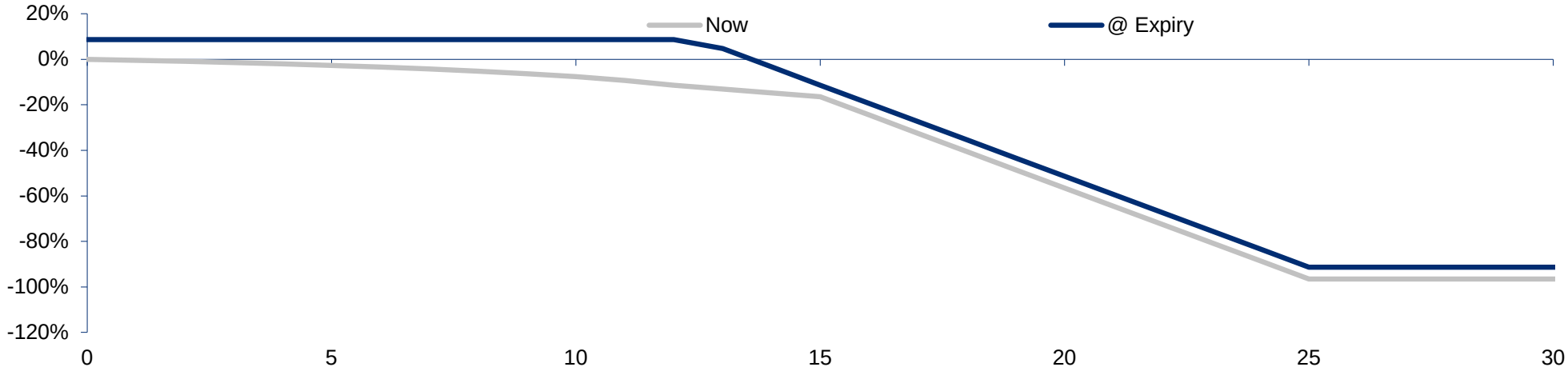
Jun-19 3-6% — P&L vs. cumulative defaults: Today and at Expiry

As of 17-Apr-14. As % of tranche notional. From a protection seller's point of view.



Jun-19 6-12% — P&L vs. cumulative defaults: Today and at Expiry

As of 17-Apr-14. As % of tranche notional. From a protection seller's point of view.



Source: Citi Research

Agenda

- Tranche risk exposures
  - Delta
  - Jump-to-default
  - **Spread dispersion**
  - Implied correlation
  - Time Value
  - Summary of risk exposures

Dispersion

- **Two indices can have the same spread but very different dispersion in the spreads of their underlying credits**.
- Consider two portfolios (125 credits), both generating a Jun-19 index spread of 82bp:
  - **All credits trading at 82bp – No dispersion**
  - **10 credits trading at 500bp and 115 trading at 50bp – Very disperse portfolio**

Impact of dispersion on tranche pricing

As of 17-Apr-14.

		All credits @ 82bp		10 credits @ 500bp 115 credits @ 50bp		Difference
Tranche	**Coupon (bp)**	**Upfront**	**Spread**	**Upfront**	**Spread**	**Spread**
0-3%	100	28%	1,158	37%	1,577	**419**
12-100%	100	-1.94%	39	-2.34%	26	**-13**
Index	**100**		**82**		**82**	**0**

- The table above shows upfronts and spreads on equity and super senior tranches for the two scenarios:
  - **Senior tranches are tighter in disperse portfolios**
  - **Junior tranches are wider in disperse portfolios**
  - **Notice that the index spread is the same in our example above**

Source: Citi Research

Dispersion

- **Equity tranches**
  - Mostly affected by the probability of the first few defaults, which depends on the spread of the widest credits
  - Thus, other things equal, **very disperse portfolios make equity tranches riskier and wider**
- **Very senior tranches**
  - Mostly affected by the probability of many defaults, which depends on the spread of ALL credits, especially the very tight ones
  - Thus, other things equal, **very disperse portfolios make senior tranches less risky and tighter**
- As a consequence, other things equal:
  - **If you sell equity protection you will have negative MtM if …**
    - **The wide credits underperform the rest**
    - The dispersion on the portfolio increases
  - **If you sell super senior protection you will have negative MtM if …**
    - **The tight credits underperform the rest**
    - The dispersion on the portfolio decreases
- **Tranches allow investors to position for changes in spread dispersion**.
  - Investors cannot position for changes in spread dispersion via the index, given that it tracks average spreads.

Agenda

- Tranche risk exposures
  - Delta
  - Jump-to-default
  - Spread dispersion
  - **Implied correlation**
  - Time Value
  - Summary of risk exposures

Let's take a step back and look at implied vol in options

- Take an iTraxx Main S21 June OTM payer (100 strike) trading at 6c (when the index is trading at 72bp).
- **Main spread doesn't move** (neither the underlying single name CDS move) but the demand for hedges increases and, as people buy those payers, their cost increases to, say, 10c.
- **What has happened?**
  - **Intuitive explanation**: Investors believe the probability of Main widening above 100bp in June has increased and are willing to pay more for that payer.
  - **Model explanation**: **Implied volatility has increased**.

Implied volatility

Underlying	
Pricing date	16-Apr-14
Index	Main S21 5y
Spread	72bp

Initial option pricing	
Expiry	18-Jun-14
Type	Payer
Strike	100bp
Price	**6c**
Implied vol.	**60%**

New option pricing	
Expiry	18-Jun-14
Type	Payer
Strike	100bp
Price	**10c**
Implied vol.	**70%**

Assumption: the spread of the index and each underlying CDS stay constant.

- Everyone happy about this?

Need an options primer? Ask us

- Other facts about implied vol:
  - **Different strikes trade with different implied vol**

    This is called vol "skew" and reflects the fact that the demand for options with different strikes is different.
  - **Different expiries have different imp. vol**

    This is called vol "term structure" and reflects the fact that the demand for options with different expiries is different.

Source: Citi Research

Let’s get back to tranches

- Take an iTraxx Main S21 12-100% 5y (Jun-19) tranche trading at 34bp (when the index is trading at 72bp).
- **Main spread doesn’t move** (neither the underlying single name CDS move) but the demand for tail hedges increases and, as people buy super senior protection, its spread widens to, say, 41bp.
- What has happened?
  - **Intuitive explanation**: Investors believe the probability of experiencing >12% losses in Main (before Jun-19) has increased and they are willing to pay more for that super senior.
  - **Model explanation**: **Implied correlation has increased**.

Implied correlaton

Underlying	
Pricing date	16-Apr-14
Index	Main S21 5y
Spread	72bp

Initial tranche pricing	
Maturity	20-Jun-19
Tranche	12-100%
Spread	**34bp**
Implied corr.	**80%**

New tranche pricing	
Maturity	20-Jun-19
Tranche	12-100%
Spread	**41bp**
Implied corr.	**90%**

Assumption: the spread of the index and each underlying CDS stay constant.

- Implied correlation in tranches, so far, looks a lot like implied vol in options.
- Other facts about implied correlation:
  - **Different tranches trade with different implied correlation**

    This is called correlation “skew” and reflects the fact that the demand for tranches with different attachments is different.
  - **Different maturities have different implied correlation**

    This is called correlation “term structure” and reflects the fact that the demand for tranches with different maturities is different.

Source: Citi Research

Let’s continue comparing implied vol and implied correlation

Options implied volatility

- **What does it measure?**

How much the index spread is expected to fluctuate.

- **Higher implied vol:**

The index spread is (believed to be) going to “move around” more.

- **Changes in implied vol:**
  - **Impact option prices**
  - **But not index spreads**

Tranches implied correlation

- **What does it measure?**

How much the default risk among the index constituents is correlated (according to investors).

Two extremes:

- **Totally independent**: the default of one name doesn’t affect the default probability of any other name.
- **Perfectly correlated**: the default of one name triggers the default of all the rest.

- **Higher implied correlation?**

The default risk of the credits in the index is (believed to be) going to be more correlated in the future.

- **Changes in implied correlation:**
  - **Impact tranche upfronts / spreads**
  - **But not index spreads**

Let’s continue comparing implied vol and implied correlation

Options implied volatility

- **How do we compute it?**

We take:

- **Underlying index spread and maturity**
- **Option type, strike and expiry**
- **Option market price**

We then use an option pricing model to find which level of implied volatility generates the market option price provided index spread, maturity and option type, strike and expiry.

- Implied vol is a product of a pricing model
- But it has an intuitive explanation
- Its movements are driven by investors / supply demand for options
- When people go long implied vol, they are just positioning for: “demand to buy options will increase”

Tranches implied correlation

- **How do we compute it?**

We take:

- **Underlying index spread and maturity**
- **Spreads for all the underlying credits**
- **Tranche attachment, detachment and tenor**
- **Tranche market spread / upfront**

We then use a tranche pricing model to find which level of implied correlation generates the market tranche price provided index spread, maturity, spreads for all underlying credits and tranche attachment / detachment.

- **Implied correlation is a product of a pricing model**
- **But it has an intuitive explanation**
- **Its movements are driven by investors / supply demand for tranches**
- When people go long implied correlation, they are just positioning for: **???**

Let’s focus on tranche implied correlation now

- **Changes in implied correlation of a given tranche tell us about whether investors are willing to pay more / less for that tranche** (other things equal)
  - Other things equal?
    - Spreads of ALL the underlying single names (absolute levels and dispersion) do not change
    - No defaults
    - No time passing
- **It is a “parameter” the model generates**

Correlation going down / up means the ??? tranche is riskier

- The table below shows the MtM (from the point of view of a protection seller) of different tranches with respect to the above factors (assuming we "increase" them: spreads increase, correlation increases, a default happens and time goes by).
- **We say that a long risk junior tranche is long correlation (makes money if correlation goes up) and a senior tranche is short correlation.**

	Spreads (i.e. PDs and expected recoveries) of companies in the index	**Correlation** (of companies credit quality)	**Default** of one company	**Time** (passage of time)
Equity Tranche	- - -	+	- - - - -	+ + +
Senior Tranche	-	-	-	+
Index	- -		- -	+ +

Long correlation:

Sell equity tranche prot.

Buy senior tranche prot.

Short correlation:

Buy equity tranche prot.

Sell senior tranche prot.

Index has no correlation exposure

Source: Citi Research

Correlation: Impact on tranche prices, spreads & MtM

iTraxx Main Series 21: How upfronts and spreads change if implied correlation increases 10%

As of 28-Apr-14.

			Current pricing			Correl +10%		Change	
Tranche	**Mat.**	**Coupon**	**Upfront**	**Spread**	**Imp. Correl.**	**Upfront**	**Spread**	**Upfront**	**Spread**
0-3%	Jun-19	100	34%	897	59%	28%	728	-6%	-169
3-6%	Jun-19	100	10.7%	320	66%	8.3%	268	-2.5%	-51
6-12%	Jun-19	100	3.7%	174	75%	2.6%	151	-1.1%	-23
12-100%	Jun-19	100	-3.3%	34		-3.0%	42	0.4%	7
Index	**Jun-19**	**100**	**-1.4%**	**73**		**-1.4%**	**73**	**0.0%**	**0**

iTraxx Main Series 21 : MtM of a long risk position if correlation increases 10%

As of 28-Apr-14.

Tranche	**Jun-17**	**Jun-19**
0-3%	3.6%	6.4%
3-6%	0.7%	2.5%
6-12%	0.4%	1.1%
12-100%	-0.2%	-0.4%
Index	**0.0%**	**0.0%**

- Remember … it's not that changes in "correlation" move prices or generate MtMs
- **It's investors' demand to sell / buy protection on a tranche which moves "correlations"**
- **Correlation changes are useful because they provide an indication of whether tranche prices have moved more or less than what changes in single name spreads would have implied**

Source: Citi Research

How do you “trade” correlation? Delta-hedging

Long correlation:

Sell equity tranche prot.

Buy senior tranche prot.

Short correlation:

Buy equity tranche prot.

Sell senior tranche prot.

Index has no correlation exposure

	Spreads (i.e. PDs and expected recoveries) of companies in the index	**Correlation** (of companies credit quality)	**Default** of one company	**Time** (passage of time)
Equity Tranche	- - -	+	- - - - -	+ + +
Senior Tranche	-	-	-	+
Index	- -		- -	+ +

- Imagine that you want to be exposed to correlation changes, “hedging” your spread exposure – i.e. **Delta-hedge**
  - **If a tranche delta is 5x, the tranche has a MtM 5x higher than the index for small spread movements.**
  - **If one buys tranche protection and sells 5x index protection, the trade will be neutral to small spread moments**
- **“Long correlation” position**:
  - **Sell equity protection,** **delta-hedged by buying index protection**
  - **Buy super senior protection,** **delta-hedged by selling index protection**
- **What are the “residual” risks of a delta-hedged tranche position?**

Source: Citi Research

Agenda

- Tranche risk exposures
  - Delta
  - Jump-to-default
  - Spread dispersion
  - Implied correlation
  - **Time Value**
  - Summary of risk exposures

What is time value?

- **Definition: Gain/loss in MtM as time goes by, everything else constant.**
  - We look at time value for a given horizon, e.g. 12 months.
  - We assume the credit spreads of all underlying names “roll / slide down” their current spread curves.
    - I.e. the current 5y spread in 1y time will be equal to the current 4y spread
- **Time value has two components:**
  - **Carry**
    - If the tranche coupon is 1%, the 12m carry will be 1%
  - **Slide** (a.k.a. roll down)
    - How much the upfront of the tranche changes if we reduce its maturity.
    - If the current Jun-19 equity upfront is 34.5%, we “re-price” the tranche with a maturity 12m shorter (i.e. Jun-18) and obtain the theoretical upfront; say it’s 25.5%. In that case, the slide is ~9%.

  Thus, 12m Carry + slide: ~10% for the Jun-19 equity tranche

iTraxx Main S21 Tranches

As of 4-Apr-14.

ITRAXX21 06/19 (71 Mid)		Delta	SECBid SECAsk
0-3	33.625/34.875	6.6X	909 947
3-6	9.625/10.875	4.4X	299 326
6-12	161/176	2.6X	161 176
12-100	32.625/34.375	0.55X	32.62 34.37

Source: Bloomberg, Citi

What is time value?

12m time value – iTraxx Main S21 Tranches: Carry + Slide

As of 28-Apr-14.

Tranche	Jun-16	Jun-18
0-3%	9.2%	10.0%
3-6%	2.9%	5.9%
6-12%	1.50%	3.57%
12-100%	0.34%	0.80%
Index	**0.75%**	**1.40%**

- **Think about time value as the reduction in the risk of an instrument as time goes by, other things equal.**
- We quantify it by looking at how much the instrument will pay us during that period.

- In normal scenarios (low spreads, steep curves), time value in single name CDS and indices tends to be higher for longer dated maturities.
- In tranches, the **effect of "subordination"** magnifies this effect in senior tranches and reduces it in equity tranches.
  - **The time value in senior tranches decreases substantially as the maturity goes down**.
  - **For equity tranches, time value remains very high even in short dated maturities**.

  In the table above, moving from Jun-18 to Jun-16 maturity reduces the time value by:
  - ~50% in the index
  - More than 50% in the seniors
  - Only less than 10% in equity tranches
  - **Investors looking for time value in junior tranches should focus on short-dated maturities, whereas those looking for time value in senior tranches should focus on longer-dated maturities**.

Source: Citi Research

Time value in equity tranches

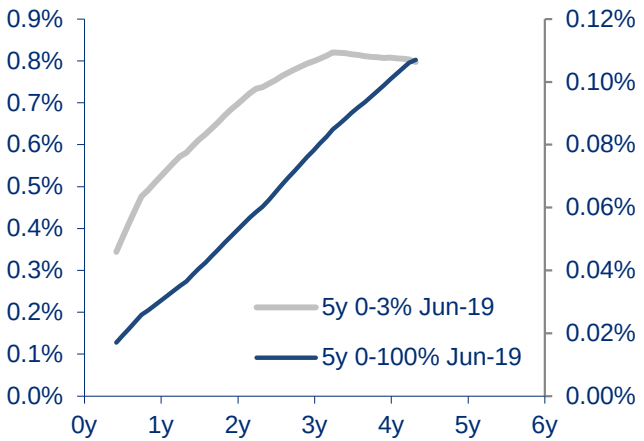
12m time value – iTraxx Main S21 Tranches: Carry + Slide

As of 28-Apr-14.

Tranche	Jun-16	Jun-18
0-3%	9.2%	10.0%
3-6%	2.9%	5.9%
6-12%	1.50%	3.57%
12-100%	0.34%	0.80%
Index	**0.75%**	**1.40%**

Equity vs. index – 1m time value vs. remaining maturity

As of 28-Apr-14. % of notional. Tranche / Index on LHS / RHS.



- **For equity tranches, time value remains very high even in short dated maturities.**
- Equity tranches are most exposed to a small number of isolated defaults
- The probability of a few isolated defaults doesn't go down that much as we increase the time horizon as long as the horizon is long enough:
- I.e. the probability of a few isolated defaults in 3y and 5y is not very different.
- However, as an equity tranche nears maturity the probability of an isolated default in the remaining months before expiry rapidly declines and so the equity tranche spread tightens significantly as the tranche nears maturity.

Source: Citi Research

Time value in senior tranches

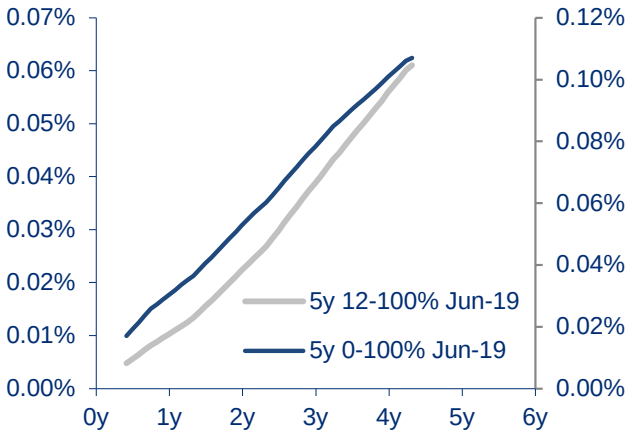
12m time value – iTraxx Main S21 Tranches: Carry + Slide

As of 28-Apr-14.

Tranche	Jun-16	Jun-18
0-3%	9.2%	10.0%
3-6%	2.9%	5.9%
6-12%	1.50%	3.57%
12-100%	0.34%	0.80%
Index	**0.75%**	**1.40%**

Senior vs. index – 1m time value vs. remaining maturity

As of 28-Apr-14. % of notional. Tranche / Index on LHS / RHS.



- **The time value in senior tranches decreases substantially as the maturity goes down.**
- Senior tranche exposure to isolated defaults is low; their biggest risk is to a large number of correlated default on the back of a full-blown systemic crisis.
- **Such an event, unlike isolated defaults, generally takes time to play out.**
- Plus, as time goes by, the subordination of senior tranches reduces their risk.
- As the maturity goes down, the subordination of senior tranches make them “virtually riskless” at some point.
  - E.g. what’s the risk of a 12-100% tranche with 3m maturity?
  - What’s the risk of an equity tranche with 3m maturity?
- Senior tranches experience higher time value (reduction of risk) for long-dated maturities
- Does a 3m of maturity reduction affect more the risk of a 12-100% tranche with 6m or with 3y maturity?

Source: Citi Research

Agenda

- Tranche risk exposures
  - Delta
  - Jump-to-default
  - Spread dispersion
  - Implied correlation
  - Time Value
  - **Summary of risk exposures**

Summary of risk exposures – across tranches

Risk exposures for S21 Main Jun-17 tranches

As of 28-Apr-14. MtM as % of notional.

As % of tranche / index notional

Tranche	Mat.	+10bp SN spreads*	12m time value	Jump-to-default**	+10% corr.
0-3%	Jun-17	-3.15%	9.01%	-14.47%	3.53%
3-6%	Jun-17	-1.20%	2.78%	-0.79%	0.69%
6-12%	Jun-17	-0.65%	1.44%	-0.19%	0.34%
12-100%	Jun-17	-0.17%	0.33%	-0.01%	-0.17%
Index	**Jun-17**	**-0.32%**	**0.73%**	**-0.48%**	**0.00%**

* Additive spread shock in all single names
** Widest credit defaults instantaneously
*** Such that all tranches have the same spread exposure than the index

Normalised by spread exposure***

Tranche	Mat.	+10bp SN spreads*	12m time value	Jump-to-default**	+10% corr.
0-3%	Jun-17	-0.32%	0.91%	-1.47%	0.36%
3-6%	Jun-17	-0.32%	0.74%	-0.21%	0.18%
6-12%	Jun-17	-0.32%	0.71%	-0.09%	0.17%
12-100%	Jun-17	-0.32%	0.62%	-0.02%	-0.31%
Index	**Jun-17**	**-0.32%**	**0.73%**	**-0.48%**	**0.00%**

Adjusting for spread risk

- Longs in junior tranches have higher time value at the expense of much higher default-exposure.
- Plus a long correlation exposure.

Thus:

- **Want to take default risk? Equity**
- **Want to take systemic risk with little default risk? Seniors**

Junior tranches have higher time value per unit of spread risk

The opposite for senior tranches.

At the expense of a very large default exposure

Long correlation exposure for junior tranches

Short for senior tranches. Not very different, in absolute terms, between the correlation exposure of equity and super senior tranches, once we adjust for spread exposure.

Source: Citi Research

Summary of risk exposures – across maturities

Risk exposures for S21 Main Jun-17 & Jun-17 tranches

As of 28-Apr-14. MtM as % of notional.

*** Such that all tranches have the same spread exposure than the Jun-17 index

Normalised by spread exposure***

Tranche	Mat.	+10bp SN spreads*	12m time value	Jump-to-default**	+10% corr.
0-3%	Jun-17	-0.32%	0.91%	-1.47%	0.36%
3-6%	Jun-17	-0.32%	0.74%	-0.21%	0.18%
6-12%	Jun-17	-0.32%	0.71%	-0.09%	0.17%
12-100%	Jun-17	-0.32%	0.62%	-0.02%	-0.31%
Index	**Jun-17**	**-0.32%**	**0.73%**	**-0.48%**	**0.00%**

Normalised by spread exposure***

Tranche	Mat.	+10bp SN spreads*	12m time value	Jump-to-default**	+10% corr.
0-3%	Jun-19	-0.32%	1.07%	-1.29%	0.68%
3-6%	Jun-19	-0.32%	0.94%	-0.24%	0.39%
6-12%	Jun-19	-0.32%	0.89%	-0.11%	0.28%
12-100%	Jun-19	-0.32%	0.78%	-0.02%	-0.37%
Index	**Jun-19**	**-0.32%**	**0.87%**	**-0.29%**	**0.00%**

- **Correlation exposure is larger for longer dated tranches**.
- **Jump-to-default in equity is larger for short dated tranches**, the opposite for the rest.
- Time value is higher for longer dated tranches.
  - Although the difference between long and short dated tranches is low for equity tranches and high for senior tranches

Source: Citi Research

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- Tranche risk exposures
- **Delta-hedging**
- Popular strategies
- Pricing
- Other topics

Delta hedged tranche trades

- Imagine we **trade the tranche against its delta** (i.e. buy/sell tranche protection vs. sell/buy index protection); we would be **hedged against small movements in spreads**, but we would still have **exposure to**:
  - **Defaults**
  - **Large spread movements**
  - **Not uniform spread movements across single names (i.e. changes in dispersion)**
  - **Time passing by**
  - **"Correlation"**

	Spreads (i.e. PDs and expected recoveries) of companies in the index	**Correlation** (of companies credit quality)	**Default** of one company	**Time** (passage of time)
Equity Tranche	- - -	+	- - - - -	+ + +
Senior Tranche	-	-	-	+
Index	- -		- -	+ +

Source: Citi Research

Convexity – Delta-hedged tranches

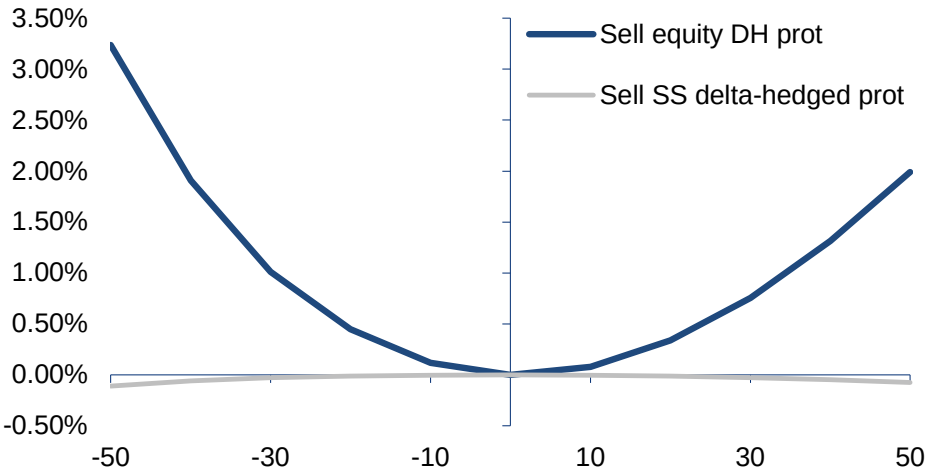
Jun-19 iTraxx Main Series 21 tranches, as of 28-Apr-14. Deltas used: 6x equity; 0.63x super senior.

- In order to gain **positive convexity (gamma)** to large spread movements:
  - **Sell equity protection, delta hedged**
  - **Buy super senior protection, delta hedged**

- **Equity tranches** (long risk, delta-hedged) **– positive convexity**
- **Senior tranches** (long risk, delta-hedged) **– negative convexity**

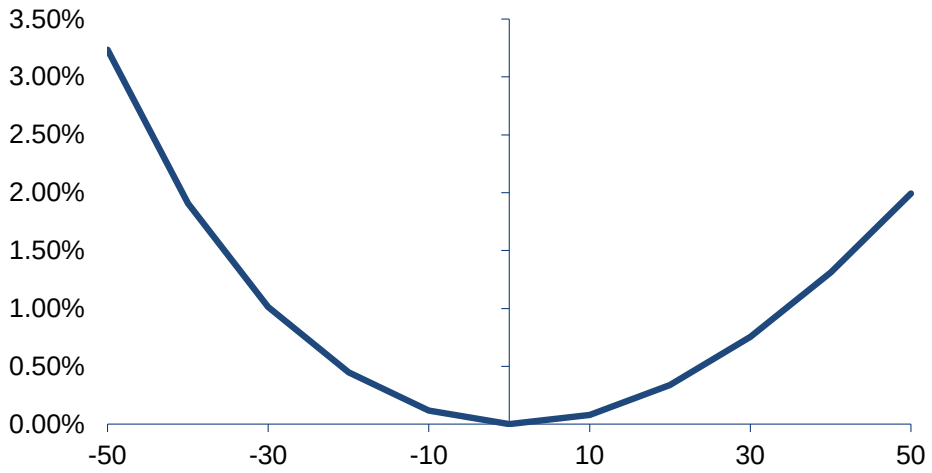
Sell equity & super senior prot; delta-hedged

Y-axis: P&L as % of tranche notional; X-axis: single name spread changes (bp)



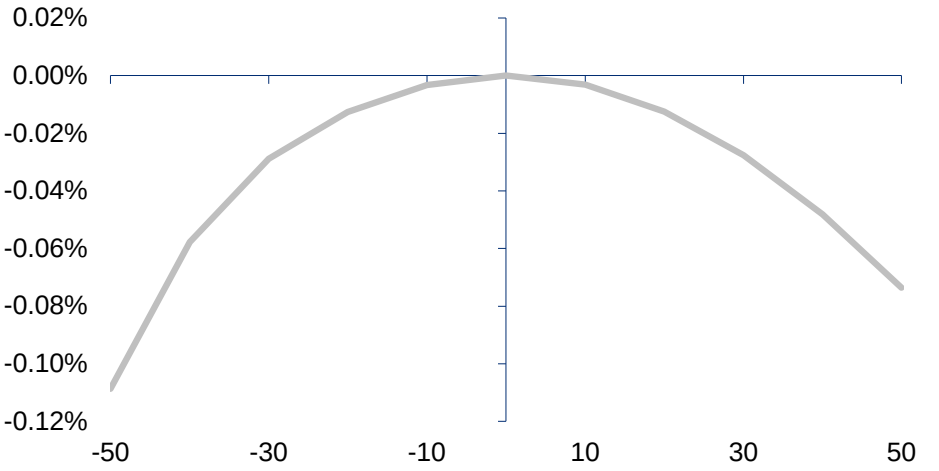
Sell equity protection, delta-hedged (6x)

Y-axis: P&L as % of tranche notional; X-axis: single name spread changes (bp)



Sell super senior protection, delta-hedged (0.63x)

Y-axis: P&L as % of tranche notional; X-axis: single name spread changes (bp)



Source: Citi Research

“Correlation” exposure – Delta-hedged tranches

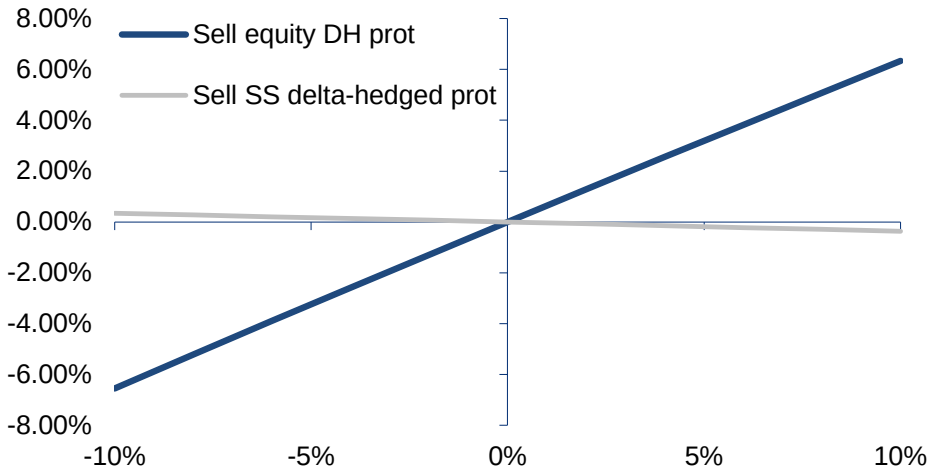
Jun-19 iTraxx Main Series 21 tranches, as of 28-Apr-14. Deltas used: 6x equity; 0.63x super senior.

- Positive convexity trades come with **long correlation** exposure
  - **Sell equity protection, delta hedged**
  - **Buy super senior protection, delta hedged**

- **Equity tranches** (long risk, delta-hedged) **– long correlation**
- **Senior tranches** (long risk, delta-hedged) **– short correlation**

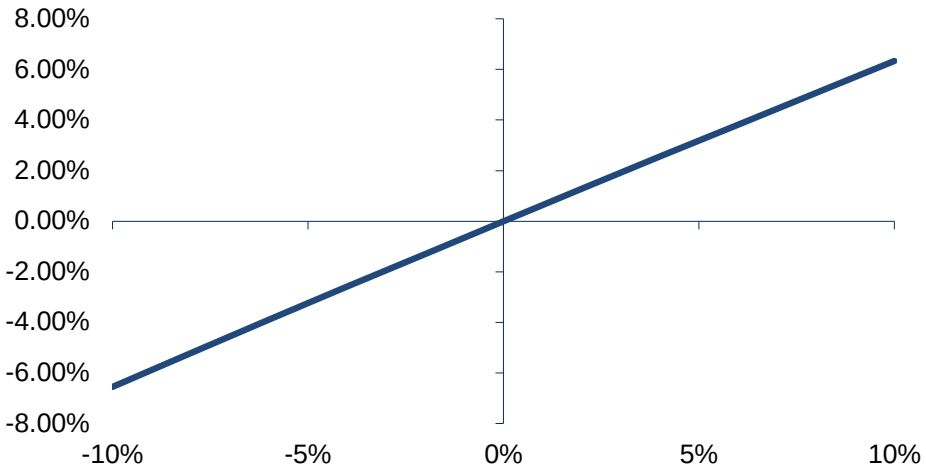
Sell equity & super senior prot; delta-hedged

Y-axis: P&L as % of tranche notional; X-axis: correlation additive changes (%)



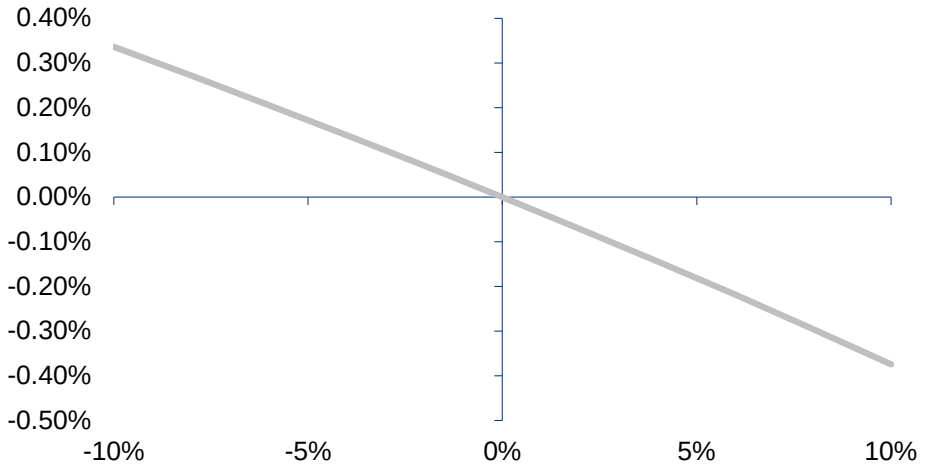
Sell equity protection, delta-hedged (6x)

Y-axis: P&L as % of tranche notional; X-axis: correlation additive changes (%)



Sell super senior protection, delta-hedged (0.63x)

Y-axis: P&L as % of tranche notional; X-axis: correlation additive changes (%)



Source: Citi Research

Time value – Delta-hedged tranches

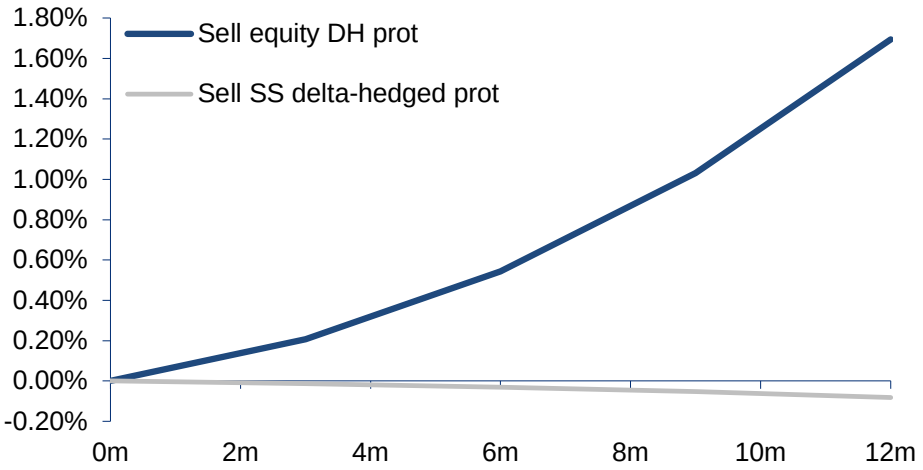
Jun-19 iTraxx Main Series 21 tranches, as of 28-Apr-14. Deltas used: 6x equity; 0.63x super senior.

- Positive convexity trades come with long correlation exposure and **positive time value**
  - **Sell equity protection, delta hedged**
  - **Buy super senior protection, delta hedged**

- **Equity tranches** (long risk, delta-hedged) **– positive time val.**
- **Senior tranches** (long risk, delta-hedged) **– negative time val.**

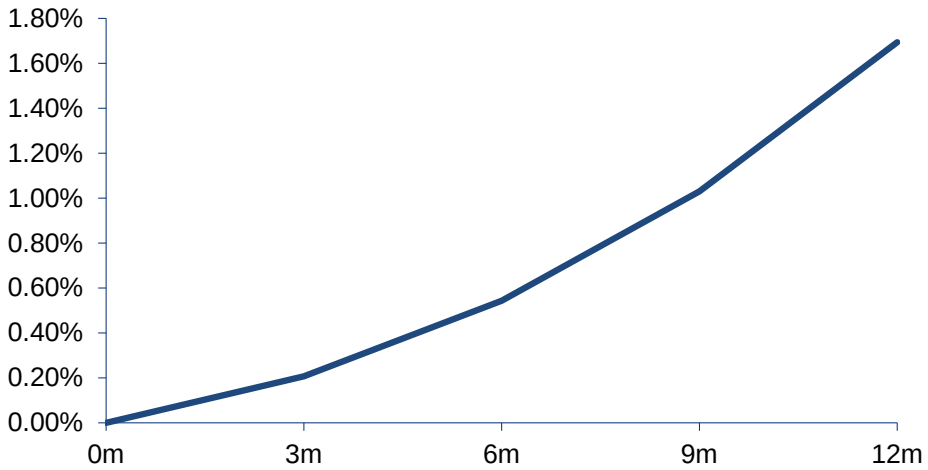
Sell equity & super senior prot; delta-hedged

Y-axis: P&L as % of tranche notional; X-axis: months passing by



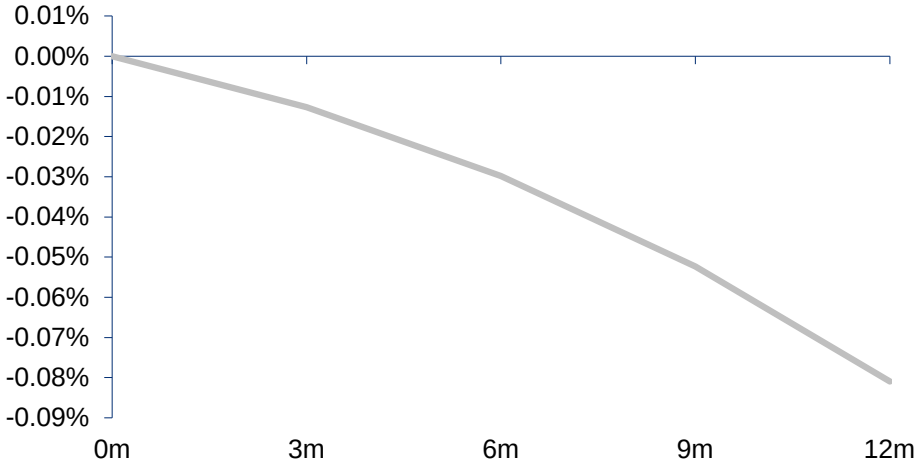
Sell equity protection, delta-hedged (6x)

Y-axis: P&L as % of tranche notional; X-axis: months passing by



Sell super senior protection, delta-hedged (0.63x)

Y-axis: P&L as % of tranche notional; X-axis: months passing by



Source: Citi Research

Jump-to-Default – Delta-hedged tranches

Jun-19 iTraxx Main Series 21 tranches, as of 28-Apr-14. Deltas used: 6x equity; 0.63x super senior.

- Positive convexity trades come with long correlation exposure, positive time value and **negative jump-to-default**
  - **Sell equity protection, delta hedged**
  - **Buy super senior protection, delta hedged**

Sell equity & super senior prot; delta-hedged

P&L as % of tranche notional

Jump-to-Default	**Widest**	**Tightest**
Sell equity DH protection	**-9.27%**	**-9.29%**
Sell super senior DH protection	**0.26%**	**0.27%**

GLEINT 5y CDS (bp)	NESTLE 5y CDS (bp)
165	24

- **Equity tranches** (long risk, delta-hedged) **– negative JtD.**
- **Senior tranches** (long risk, delta-hedged) **– positive JtD.**

Source: Citi Research

Dispersion – Delta-hedged tranches

- Positive convexity trades come with long correlation exposure, positive time value, negative jump-to-default and **"short dispersion"** (i.e. make money if dispersion goes down)
  - **Sell equity protection, delta hedged**
  - **Buy super senior protection, delta hedged**

- **Equity tranches** (long risk, delta-hedged) **– short dispersion**
- **Senior tranches** (long risk, delta-hedged) **– long dispersion**

Source: Citi Research

Delta-hedged tranches

- **Selling equity or buying super senior protection, delta-hedged**, offers:
  - **Systemic protection**: positive MtM if correlation increases and/or if dispersion falls
  - **Positive convexity** if spreads move, uniformly, either way
  - You even get **positive time value**

  - **How do you pay for this? Negative MtM if idiosyncratic risks increase (defaults or higher dispersion)**

Source: Citi Research

Delta-hedged tranches – Selling tranche protection

Jun-19 iTraxx Main Series 21 tranches, as of 28-Apr-14.

As % of notional; no delta-hedged

Tranche	Mat.	+50bp SN spreads*	12m time value	Jump-to-default**	+10% corr.	Delta
0-3%	Jun-19	-12.97%	9.98%	-12.00%	6.34%	6.0x
3-6%	Jun-19	-9.39%	5.81%	-1.50%	2.40%	3.9x
6-12%	Jun-19	-6.25%	3.52%	-0.43%	1.11%	2.5x
12-100%	Jun-19	-1.64%	0.79%	-0.02%	-0.37%	0.63x
Index	**Jun-19**	**-2.49%**	**1.38%**	**-0.46%**	**0.00%**	**1x**

* Additive spread shock in all single names

** Widest credit defaults instantaneously

As % of tranche notional; delta-hedged

Tranche	Mat.	+50bp SN spreads*	12m time value	Jump-to-default**	+10% corr.
0-3%	Jun-19	2.03%	1.7%	-9.3%	6.3%
3-6%	Jun-19	0.31%	0.4%	0.3%	2.4%
6-12%	Jun-19	-0.10%	0.1%	0.7%	1.1%
12-100%	Jun-19	-0.07%	-0.1%	0.3%	-0.4%

As % of tranche notional; DH. Normalised by equity corr. Exposure***

Tranche	Mat.	+50bp SN spreads*	12m time value	Jump-to-default**	+10% corr.
0-3%	Jun-19	2.03%	1.7%	-9.3%	6.3%
3-6%	Jun-19	0.81%	1.2%	0.7%	6.3%
6-12%	Jun-19	-0.59%	0.7%	3.9%	6.3%
12-100%	Jun-19	-1.22%	-1.4%	4.5%	-6.3%

*** Such that all tranches have the same (absolute) correlation exposure than the equity tranche

Source: Citi Research

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Recently …

- **A selected but faithful group of hedge fund investors have sold no-delta equity tranche protection over the past few years**
  - With some tail-hedges
  - And with very large returns as equity tranches outperformed everything (see later section)
  - Starting with short dated equity tranches and extending maturities as spreads tightened
  - **"Sophisticated" real money investors have been sellers of Mezzanine protection, to pick up high spreads with default subordination**
  - Nowhere near the volumes done back in 2004-7.

- **"Deep-pocket" hedge funds and macro investors have recently started selling super senior protection**
- Given how high correlations are on the back of the demand for equity tranches.

- **The market has become a long-only one, with very little "correlation" or "relative value" trading**
- Similar to cash structured products like CLOs

iTraxx Main S9 Jun-18 Returns As of 29-Apr-14

P&L as % of tranche notional.

10y - Tranche performance

From a protection seller's point of view, as % of notional on each instrument.

	No delta-hedged performance			Delta-hedged performance		
	6m	12m	18m	6m	12m	18m
0-3%	17.1%	34.0%	53.2%	**2.6%**	**6.9%**	**14.6%**
3-6%	10.9%	23.1%	39.5%	**1.5%**	**3.7%**	**7.6%**
6-9%	6.8%	15.1%	27.0%	**0.5%**	**1.9%**	**4.0%**
9-12%	4.5%	10.0%	17.3%	**0.2%**	**0.8%**	**0.8%**
12-22%	1.8%	4.5%	8.7%	**-0.7%**	**-1.0%**	**-1.2%**
22-100%	0.7%	1.4%	2.4%	**-0.1%**	**-0.4%**	**-0.9%**
Ref	**1.9%**	**4.0%**	**6.9%**			

Source: Citi Research

Before the credit crisis

- **Real money investors sold mezzanine protection (in size)**
- **Monolines / conduits sold super senior protection (levered)**
- **Hedge funds sold equity protection (delta-hedged)**
- **Plenty of “correlation” and “relative value” trading**

Where are we heading?

- **Tranches are the most pro-cyclical product out there**
  - Shunned by investors when they can get high spreads in unlevered products
  - Only alternative to get high spreads when market spreads are tight enough
- **The history is a bit dark … but financial memory is very short**

- **What will happen if Main is below 60bp?**
  - **Anything can happen … that’s why refreshing your tranche skills is worth your time**

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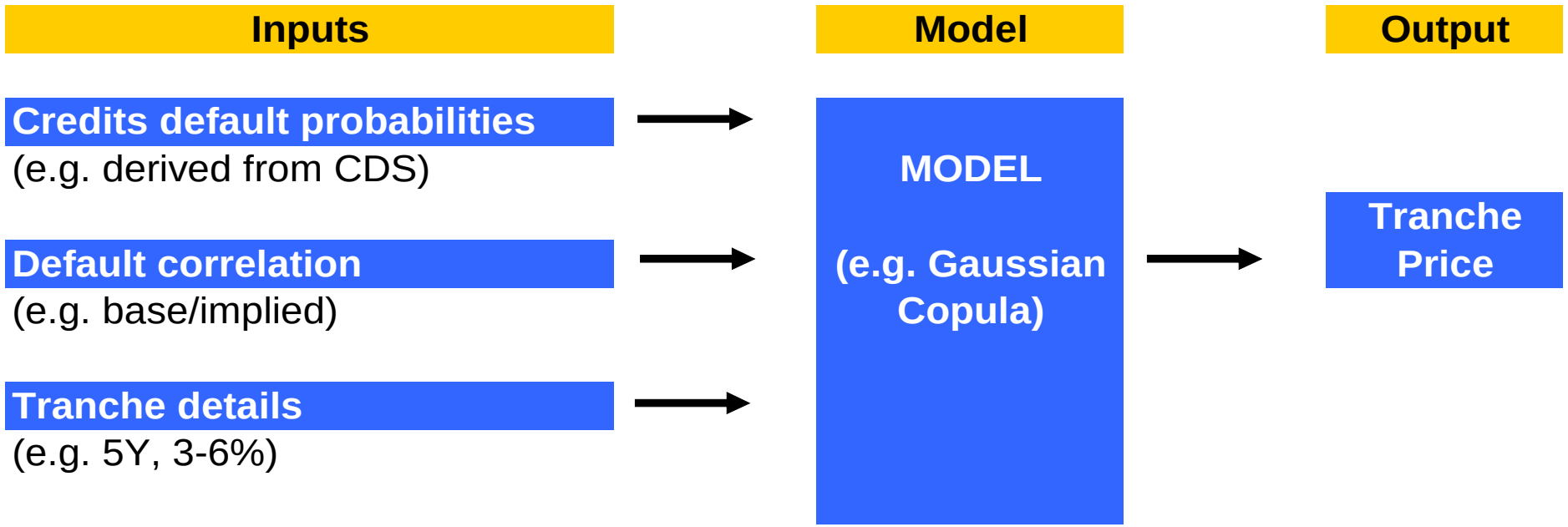
Tranche pricing

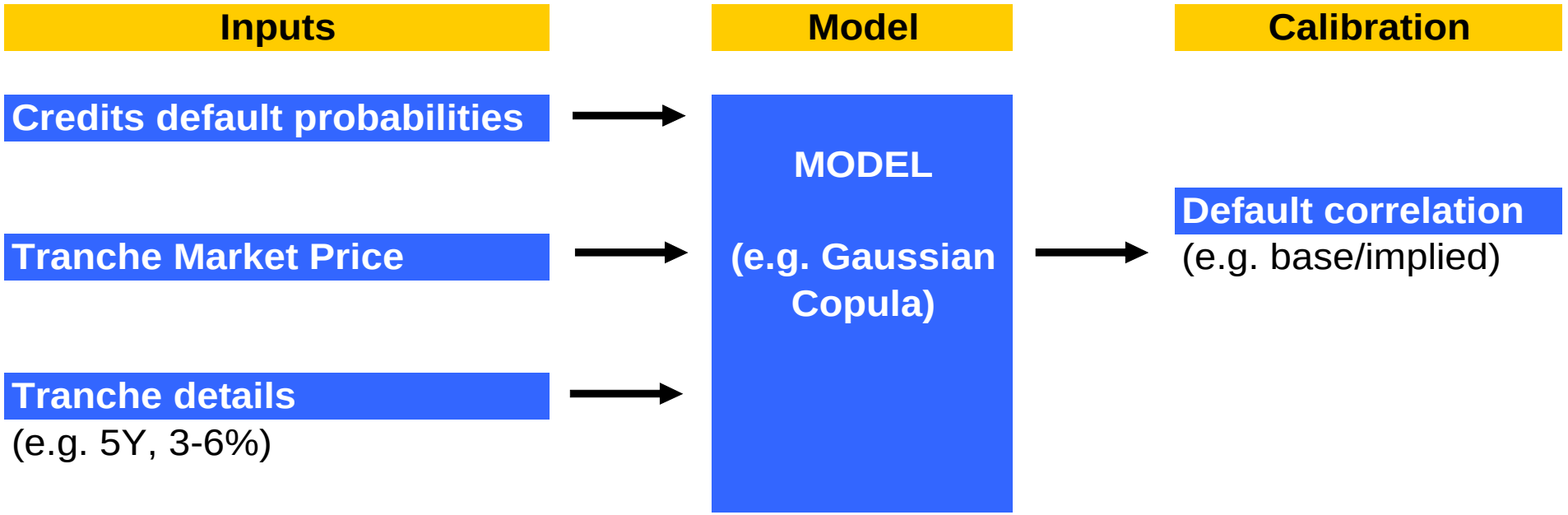


Source: Citi Research

What do we need to price a tranche?

- Tranche characteristics:
  - **Maturity** (e.g. 5y)
  - **Subordination** (e.g. 3-6%)
- **Recovery rate**: deterministic assumption to start with (e.g. 40%); or a more sophisticated stochastic/random model.
- Default probabilities of the underlying credits in the portfolio:
  - Can be obtained using a reduced or structural model
  - Usual practice: calibrate an intensity model to the firm's **CDS spreads**
- **Default Correlation:**
  - In the single risk factor copula model (standard model to price tranches), default correlation is introduced through a "correlation" parameter, which is supposed to be forward looking (i.e. capture future correlation).
  - It is not very practical to estimate it.
  - **But we can calibrate it**, can't we? I.e. we can look at tranche prices and figure out the **"implied" correlation** the market is using.
  - Don't we do the same when pricing options? We derive the "implied volatility" from the market price of the option using the Black-Scholes model … the wrong parameter in the wrong model which gives the right price …

Default Correlation Calibration



- We can compute implied correlation provided we have a market price for the tranche, which is fine for standard index tranches …
- But for bespokes?

Source: Citi Research

For bespoke tranches, correlation is an input

Input: The standard index tranche market (iTraxx, CDX)

Index Tranche spread + **Additional information** → **Model** → **Correlation**

Maturity,
Attachments,
Detachments,
Portfolio CDS

All of these are
"**standard**"

iTraxx, CDX are the benchmark for correlation

Output: Bespoke tranche price

Tranche spread ← **Model** ← **Additional information** + **Correlation**

Maturity,
Attachments,
Detachments,
Portfolio CDS

Any of these can be
"**bespoke**"

Source: Citi Research

Implied Correlation

- For each tranche we know:
  - Default probabilities of the credits in the underlying portfolio (via CDS spreads)
  - Recovery rates (we can assume something like 40% … or be a bit more sophisticated and use a random/stochastic model)
  - Model we use
  - Market price
- The only “free” parameter is the correlation parameter, which we can calibrate such that the model gives us the exact market price
- So we have an **“implied” correlation for each tranche**
- If the model is correct, all implied correlations should be the same.
  - However …that is not the case: implied correlation is different for each tranche.
  - Why?
    - Segmentation among investors across tranches, and these investor groups hold different views about correlations
    - Local demand conditions in prices
  - **Like implied vol in options, implied correlation in tranches is a reflection of the supply/demand imbalance in the market**
  - **Different supply/demand of risk on each tranche generates a different implied correlation.**

Problems of Implied Correlation

- Many, among others:
  - We can only guarantee its **existence** for the equity tranche – **no correlation for mezz tranches**
  - We can only guarantee its **uniqueness** for the equity tranche – **two correlations for mezz tranches**

- This poses important challenges to day-to-day market practices:
  - Compute the sensitivity of mezzanine tranches to correlation
    - We have a position on a mezzanine tranche and we want to know how sensitive it is to default correlation
      - Do we make or lose money if correlations increase?
      - For that, we find out the implied correlation
      - And we shock it: we compute the price of the tranche by assuming a slightly higher correlation keeping all the other parameters (probabilities, recoveries, …) constant
    - We compute its implied correlation and … it has two implied correlations … or … it has none.
    - Which one do we shock?
  - Price bespoke tranches by interpolating correlations on standard tranches

Base Correlation

- Base correlations are “cousins” of implied correlations which solve some of their problems (but introduce others)
- They have replaced implied correlations as the market standard to talk about default correlation
- Idea:
  - Implied correlations do not give problems for equity tranches: they exist and they are unique
  - Any tranche (e.g. long 3-6%) can be expressed as two equity tranches (long 0-6% & short 0-3%)

- **Base correlation is the correlation of base tranches: 0-3%, 0-6%, 0-12%, …**
- **Implied correlations referred to the “real” tranches 0-3%, 3-6%, 6-12%, …**

- Same model than implied correlations
- **Base correlations are by definition correlations of equity tranches:**
  - **They are unique and we can guarantee that they exist**
  - Monotonic impact on tranche spread and MtM
- They solve some of the problems of implied correlations
- But not all, and can even more difficult to interpret or understand

Main S21 Base Correlations

As of 29-Apr-14

Attachment	3y Jun-17	5y Jun-19
3%	58%	59%
6%	67%	66%
12%	77%	75%

Source: Citi Research

Further references on tranche pricing

- "**Credit Derivatives: under the bonnet**", Citi, 2010.
- "**Understanding and Pricing CDOs**" – A. Elizalde. 2005

- "**Modelling Single-Name and Multi-Name Credit Derivatives**" – D. O'Kane. 2008.
  - Chp. 12, Sections 12.4-12.9 : "An Introduction to Correlation Products"
  - Chp. 13: "The Gaussian Latent Variable Model"
  - Chp. 16: "Pricing Tranches in the Gaussian Copula Model"
  - Chp. 17: "Risk management of synthetic tranches"
  - Chp. 18: "Building the Full Loss Distribution"
  - Chp. 19: "Implied Correlation"
  - Chp. 20: "Base Correlation"

- "**Credit Derivatives: CDOs & Structured Credit Products**" – S. Das. 2005.
  - Section 8.4.2: "Single Tranche CDOs"
  - Section 9.2.1: " CDO Investments – Economic/Risk Analysis: Overview"

Less technical and more intuitive analysis of the history and risks of standard synthetic tranches than O'Kane's chapter.

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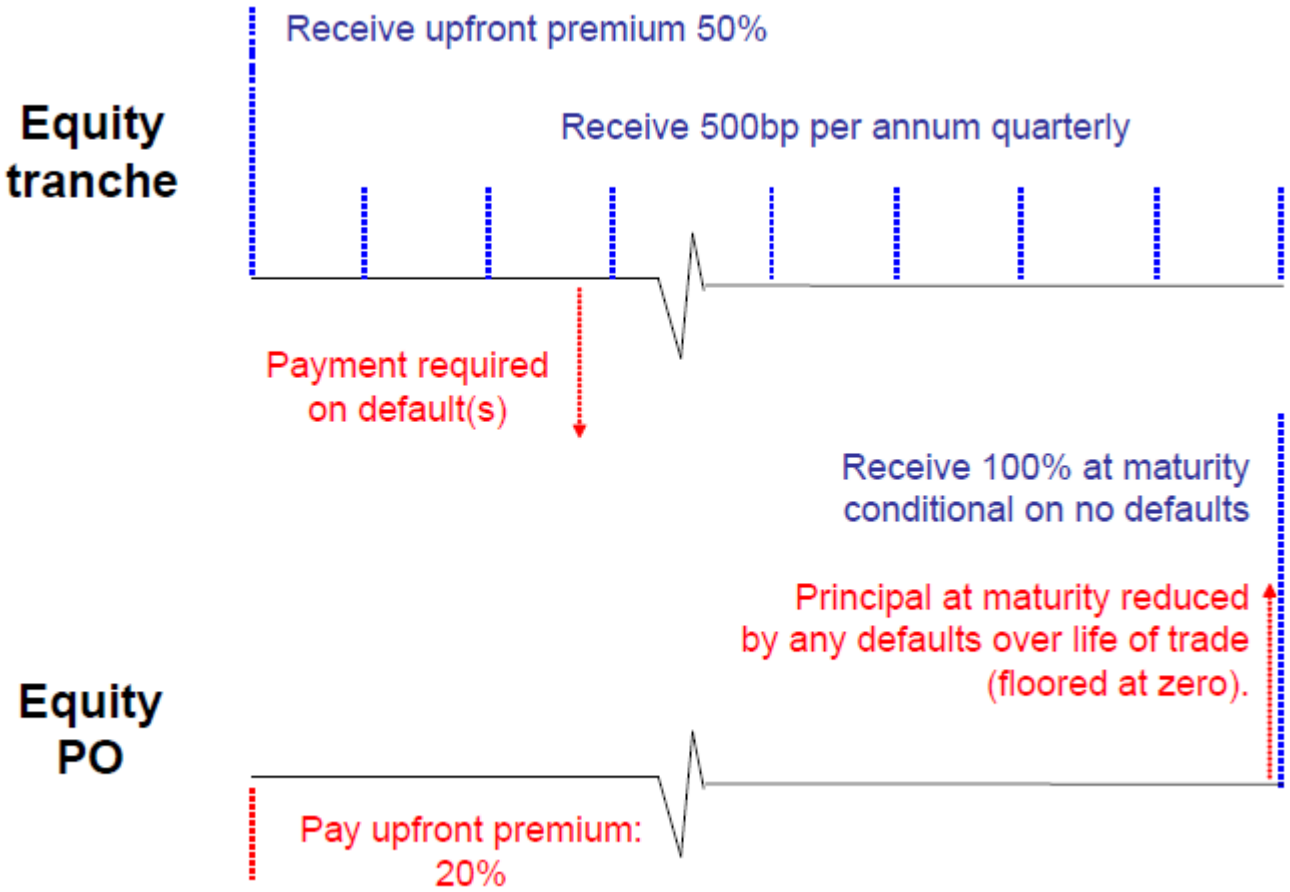
- Other topics
  - **Zero-coupon notes (a.k.a “POs”)**
  - Recent cumulative returns
  - Tranches vs. Options
  - Expected loss ratio – fraction of index risk allocated to each tranche
  - Super Senior Outstanding Notional
  - Securitisation & Liquidity: Their Role in The Boom & Bust

Zero-coupon notes (a.k.a “POs”)

- It is essentially a **funded zero coupon bond** which is **exposed to equity** (or sometimes junior mezzanine) **default risk**.
  - An investor pays a heavily discounted price for the zero coupon bond and receives no further cash flow until maturity.

- POs are popular with some investors because they are a method of taking highly leveraged exposure to the credit market without the complications, and all the requirements, of investing in synthetic tranches.
- See: *Saddle-up with Zero Coupon Tranches*, 22-Apr-10.

Cash flows of an equity PO versus a standard equity tranche



Source: Citi Research

Zero-coupon notes (a.k.a “POs”)

- Mechanics: **An investor buying and equity PO note** (i.e. going long risk) with 100€ notional will:
  - **Pay an upfront amount (the PO price, expressed as % of the notional) at the time of entering the trade**. For example, if the PO price is 20%, the investor will pay 20€ at inception.
  - **No further cash-flows until maturity**.
  - **Receive, at maturity, an amount equal to the initial notional less any default losses born by the equity tranche from inception to maturity**. In iTraxx Main, the loss for the 0-3% tranche of one default is equal to 1 / 125 x (1 – recovery) / 3%. Assuming a 40% recovery, each default generates a loss of 16%. Thus, if there is one default from inception to maturity, the investor will receive 84€ (=100 – 16) at maturity; if there are two defaults, he will receive 68€, and so on.
  - **There are no payments involved during the life of the transaction except at inception and at maturity**.
  - Remember than in standard equity tranches, defaults are settled as they happen.
  - A PO note is like a zero coupon bond whose payment at maturity is linked to the default losses of an equity tranche.
  - **The maximum loss for a PO buyer is equal to the PO price (times notional)**.
  - **The final P&L / return of a PO note depends exclusively on the number of default losses, not on their timing.**
  - In standard equity tranches, the timing of defaults will impact the coupons received during the transaction.
  - **PO notes vs. standard tranches:**
  - PO notes are not sensitive to the timing of defaults; standard tranches benefit from back-dated defaults.
  - PO notes are negatively impacted by higher rates; standard tranches benefit from higher rates.

Source: Citi Research

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- Other topics
  - Zero-coupon notes (a.k.a “POs”)
  - **Recent cumulative returns**
  - Tranches vs. Options
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European Credit Derivatives Returns – Daily Analytics Report

- Link for the daily report on Citi Velocity: **European Credit Derivatives Returns**

Unfunded CDS indices, options and tranches

Return of a long risk position as % of notional traded. Daily delta-hedged for options/tranches.

As of 29-Apr-14

CDS Indices

	1m	3m	12m
Main	0.3%	1.2%	3.3%
Sen. Fin.	0.7%	1.9%	5.9%
Xover	0.7%	5.1%	14.0%

iTraxx Main Steepeners (DVO1-weighted)

	1m	3m	12m
3s5s	-0.1%	-0.2%	-0.7%
5s10s	0.1%	0.3%	1.4%

Main S9 10y tranches Delta-hedged

	1m	3m	12m
0-3%	-0.2%	-0.1%	6.9%
3-6%	-0.4%	-0.9%	3.8%
6-9%	0.0%	-0.4%	2.0%
9-12%	-0.1%	0.0%	0.8%
12-22%	-0.1%	-0.3%	-0.9%
22-100%	0.0%	0.1%	-0.4%

Main Straddle Delta-hedged

	1m	3m	12m
1m	0.1%	0.3%	0.6%
3m	-0.1%	0.1%	0.2%

Source: Citi Research, Markit, Bloomberg

iTraxx Main S9 Tranches – Daily Analytics Report

- Links for the daily reports on Citi Velocity: Main S9, Main S19, Main S21.

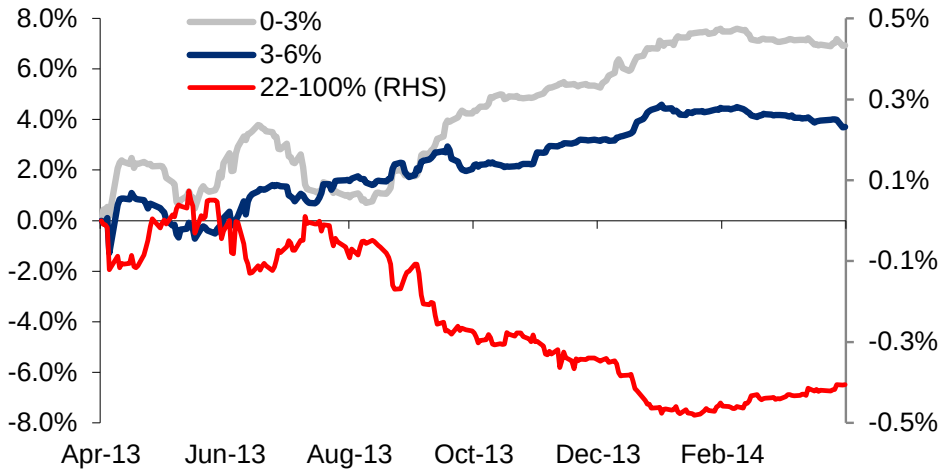
10y - Tranche performance
From a protection seller's point of view, as % of notional on each instrument.

As of 29 April 2014

	No delta-hedged performance			Delta-hedged performance		
	6m	12m	18m	6m	12m	18m
0-3%	17.1%	34.0%	53.2%	**2.6%**	**6.9%**	**14.6%**
3-6%	10.9%	23.1%	39.5%	**1.5%**	**3.7%**	**7.6%**
6-9%	6.8%	15.1%	27.0%	**0.5%**	**1.9%**	**4.0%**
9-12%	4.5%	10.0%	17.3%	**0.2%**	**0.8%**	**0.8%**
12-22%	1.8%	4.5%	8.7%	**-0.7%**	**-1.0%**	**-1.2%**
22-100%	0.7%	1.4%	2.4%	**-0.1%**	**-0.4%**	**-0.9%**
Ref	**1.9%**	**4.0%**	**6.9%**			

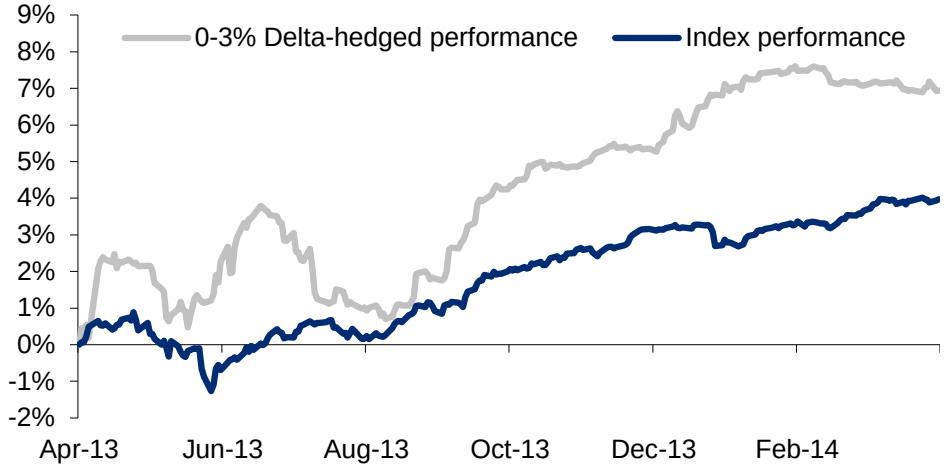
Sell delta-hedged protection – Cum. Returns

P&L as % of tranche notional.



Outright index long vs. equity delta-hedged

P&L as % of tranche notional.



Source: Citi Research, Markit, Bloomberg

Agenda

- Other topics
  - Zero-coupon notes (a.k.a “POs”)
  - Recent cumulative returns
  - **Tranches vs. Options**
  - Expected loss ratio – fraction of index risk allocated to each tranche
  - Super Senior Outstanding Notional
  - Securitisation & Liquidity: Their Role in The Boom & Bust

Tranches vs. Options

- **In tranches positive convexity comes with positive time value – the main cost being very negative default risk.**
- **In options, one pays with negative time value for positive convexity.**

	Sell equity tranche protection (delta-hedged)	Sell options (delta-hedged)	
Spread exposure Sensitivity to small spread movements	**Neutral**	**Neutral**	
Convexity / Gamma Sensitivity to large spread movements	**Positive**	**Negative**	**Different convexity sign**
Dispersion Sensitivity to dispersion increasing	**Negative**	**Neutral**	
Theta / Time value MtM from time passing	**Positive**	**Positive**	**With the same time value sign**
Jump-to-default MtM upon an instantaneous default	**Negative**	**Small -ve**	
Implied vol MtM from implied vol increasing	**Neutral**	**Negative**	
Implied correlation	**Positive**	**Neutral**	

- Past trade idea: **Sell equity tranche protection & sell straddles**, 20-Feb-14. [LINK]

Source: Citi Research

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Expected Loss Ratio

- **The sum of the parts equals the total**
  - Risk in the underlying portfolio / index = Sum of the risk on each tranche
  - **What's the percentage of the index risk which each tranche captures?**
  - This is the ELR of each tranche.
  - The sum of all tranches ELRs adds up to 100%.

- **How does the ELR move?**

Equity ELR goes up, Senior ELR goes down …

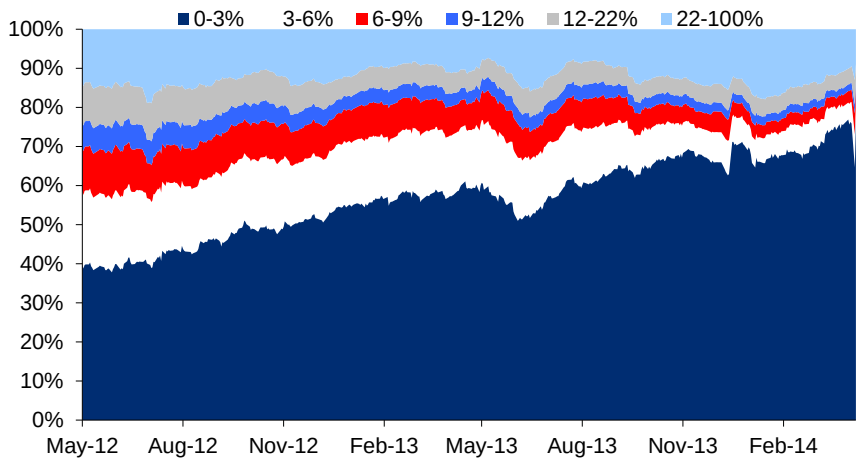
  - As time to maturity goes down
  - As index spreads tighten
  - As correlation goes down
  - As dispersion goes up

ELR Main Series 9 Tranches

As of 29-Apr-14.

Series 9	Jun-15	Jun-18
0-3%	77%	39%
3-6%	4%	14%
6-9%	3%	8%
9-12%	2%	5%
12-22%	4%	9%
22-100%	9%	24%

Historical ELR Main Series 9 Jun-15 Tranches



Source: Citi Research

Expected Loss Ratio

- **How is it computed?**
  - Index expected loss = spread x duration
  - Tranche expected loss = spread x duration = upfront + coupon x duration
  - Since the sum of the widths of all tranches is equal to one, i.e. to the index, we scale the expected loss of each tranche by its width.
  - The sum of those tranche expected losses adds up to the index expected loss.
  - We then take the ratio of each tranche (width-weighted) expected loss and the index expected loss to obtain the fraction of the index expected loss (risk) allocated to each tranche; this is the expected loss ratio.

ELR Main Series 9 Jun-18 Tranches

As of 29-Apr-14.

	Upfront	Spread	Coupon	RA	Exp. Loss Level	Exp. Loss Ratio
0-3%	17.3%	997	5.00%	3.48	35%	39%
3-6%	-7.4%	312	5.00%	3.96	12%	14%
6-9%	-4.9%	180	3.00%	4.05	7%	8%
9-12%	0.5%	112	1.00%	4.09	5%	5%
12-22%	-1.6%	61	1.00%	4.13	3%	9%
22-100%	-0.2%	20	0.25%	4.11	1%	24%
Ref	-4.5%		1.75%	4.07	3%	

Source: Citi Research

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Tranche outstanding notional – Remember for non-SS tranches

- **Tranche losses are paid as and when they happen. How is the compensation to bear those losses received?**
  - The **tranche upfront** is received at **inception** of the trade, on the initial tranche notional traded
  - The fixed **coupon** is received quarterly, **on the outstanding tranche notional at each point in time**
    - The **tranche outstanding notional is equal to the initial notional minus the losses suffered by the tranche***
    - Outst. notional is 100% of initial notional until the tranche is hit, and progressively falls to 0 as the tranche absorbs losses.
    - Once the tranche is wiped out (index default losses > detachment), the outst. notional is zero and the trade terminates.

		0-3%			3-6%		
Number of index defaults	(40% Rec) **Cummulative Index Loss**	**Index losses absorbed**	**Losses on tranche traded notional**	**Tranche Outstanding Notional**	**Index losses absorbed**	**Losses on tranche traded notional**	**Tranche Outstanding Notional**
1	0.48%	0.48%	16%	84%	0.00%	0%	100%
2	0.96%	0.96%	32%	68%	0.00%	0%	100%
3	1.44%	1.44%	48%	52%	0.00%	0%	100%
4	1.92%	1.92%	64%	36%	0.00%	0%	100%
5	2.40%	2.40%	80%	20%	0.00%	0%	100%
6	2.88%	2.88%	96%	4%	0.00%	0%	100%
7	3.36%	3.00%	100%	0%	0.36%	12%	88%
8	3.84%	3.00%	100%	0%	0.84%	28%	72%
9	4.32%	3.00%	100%	0%	1.32%	44%	56%
10	4.80%	3.00%	100%	0%	1.80%	60%	40%
11	5.28%	3.00%	100%	0%	2.28%	76%	24%
12	5.76%	3.00%	100%	0%	2.76%	92%	8%
13	6.24%	3.00%	100%	0%	3.00%	100%	0%
14	6.72%	3.00%	100%	0%	3.00%	100%	0%

Source: Citi Research *** Except for the super senior tranche (X-100%), see section in "Other topics".**

What happens in super senior tranches?

- **Super senior = X-100%, e.g. 12-100% in iTraxx S21 or 22-100% in iTraxx S9**
- **The outstanding notional of a super senior tranche** starts at 100% and inception and **goes down if:**
  - **Losses in the index go above its attachment point** – e.g. iTraxx S21 index losses go above 12%, or
  - **Defaults occur with more than 0% recovery; for any default, from the first to the last**.
  - **Take the first default in iTraxx Main S21, assuming 40% recovery:**
  - The index outstanding notional goes down 0.8% = weight of the defaulted name
  - The equity tranche outstanding notional is affected only by the "loss" fraction of that weight, i.e. 0.8% x (1 – 40%)
    - Equity outstanding notional goes down from 100% to 84%. i.e. 16% = 0.48% / 3% = index loss / tranche width
  - What do we do with the "not loss" fraction of the weight?
  - We reduce the super senior outstanding notional
    - 12-100% outstanding notional goes down from 100% to 99.64%.

      i.e. 0.36% = (0.8% - 0.48%) / 88% = (name weight - index loss) / tranche width = (name weight x recovery) / tranche width
  - **Why do you do this to us (sellers of super senior protection)?**
  - To make sure that, at any point in time, the sum of all the tranches (weighted by their width) is equal to the index.
  - **Aren't super senior protection sellers at a disadvantage?**
  - Not if the spread you are paid already prices this.
  - The spread you would be paid if the super senior outstanding notional wouldn't go down with the "recovery" amounts would be lower.

Source: Citi Research

What happens in super senior tranches?

125 Names 40% Recovery				Cumulative			Outs Notional		
Default	Weight	Assumed Recovery	Loss	Weight of defaulted names	Index Loss	Differnce	Index 0-100%	Equity 0-3%	Super Senior 12-100%
0			0.00%	0.0%	0.00%	0.00%	100%	100%	**100.00%**
1	0.8%	40%	0.48%	0.8%	0.48%	0.32%	99.2%	84%	**99.64%**
2	0.8%	40%	0.48%	1.6%	0.96%	0.64%	98.4%	68%	**99.27%**
3	0.8%	40%	0.48%	2.4%	1.44%	0.96%	97.6%	52%	**98.91%**
4	0.8%	40%	0.48%	3.2%	1.92%	1.28%	96.8%	36%	**98.55%**
5	0.8%	40%	0.48%	4.0%	2.40%	1.60%	96.0%	20%	**98.18%**
…	…	…	…	…	…	…	…	…	**…**
10	0.8%	40%	0.48%	8.0%	4.80%	3.20%	92.0%	0%	**96.36%**
…	…	…	…	…	…	…	…	…	**…**
20	0.8%	40%	0.48%	16.0%	9.60%	6.40%	84.0%	0%	**92.73%**
…	…	…	…	…	…	…	…	…	**…**
125	0.8%	40%	0.48%	100.0%	60%	40.00%	0.0%	0%	**0.00%**

1. The outstanding notional of the index goes down by the weight of the defaulted name

2. For non-super senior tranches, the outstanding notional goes down only by the "loss" implied by each default

3. For recoveries higher than 0%, there is a "missing" term … weight minus loss on each name

4. This "missing" term, the difference between the weight of the defaulted names and the losses they imply is taken out from the super senior notional

E.g. 1st default, assuming 40% recovery:

Index outs. notional goes down 0.8%

0-3% outs. notional goes down 16% = 0.48% / 3%

12-100% outs. notional goes down 0.36%

= (0.8% - 0.48%) / 88%

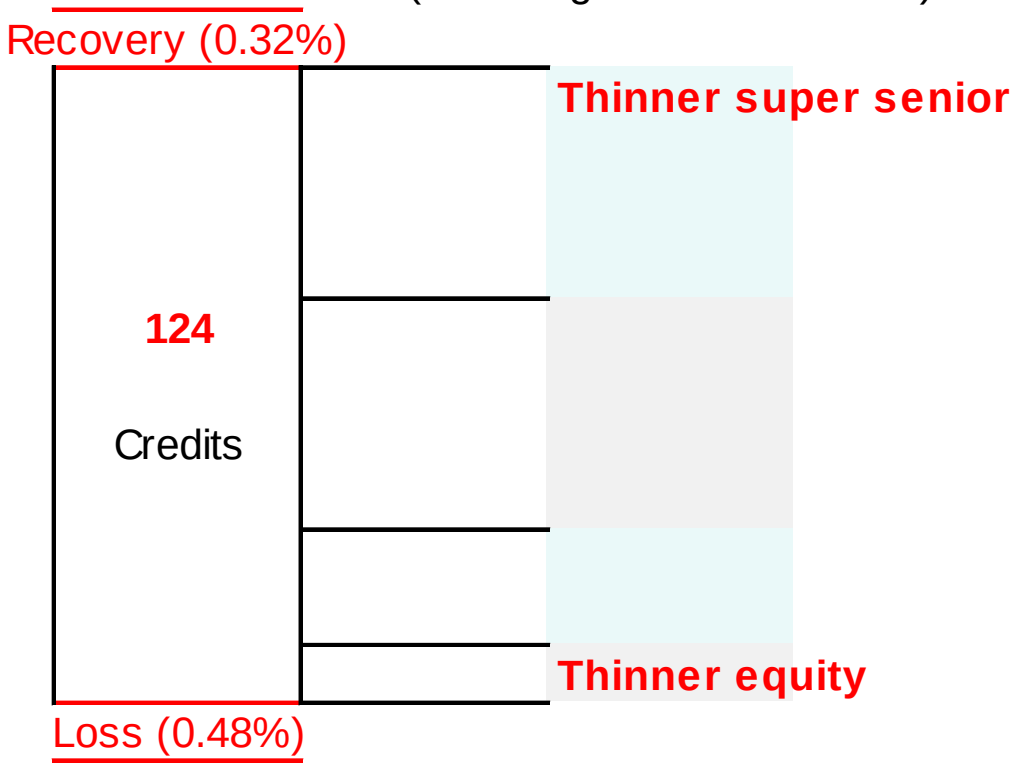
= (weight – loss) / width = weight x recovery / width.

Source: Citi Research

What happens in super senior tranches?

Initially

After 1 default



Source: Citi Research

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Securitization & Liquidity: Their Role in The Boom & Bust

- Altman (2006) wrote about an
  - "…**unprecedented growth in liquidity from non-traditional lenders, like hedge and private equity funds, as well as, again, from traditional lenders**."
  - He cites this source of liquidity as one of the main reasons behind the low default rates during previous years.

- **No other economic cycle had been so reliant on liquidity and availability of credit**
  - Why? Partly to easing monetary policy, but also to changes in lending

- **Major innovation:**
  - **Securitisation**, a process which started more than two decades ago in mortgage markets.

- The emergence of credit derivatives on investment grade and high yield corporate debt caused a further exponential boost from 2003 to 2007.

- **Securitisation generated demand from investors to buy assets which ultimately generated loans (or cheaper funding) to companies and consumers.**

Cash Securitisation

- Banks have limitations on the amount of risky assets (i.e. lending) they can hold on their balance sheets.
- When originating and structuring, a bank only keeps the risky assets on its balance sheet for a limited amount of time.
- A bank can repeat the securitisation process many times.
  - Each time, making some profit

- Banks have incentives, and are allowed, to use securitization
  - Banks can act as originators themselves
  - or source the assets externally

- **Ultimately, consumers and companies have easier access to credit**
  - **Cash securitisation increases the liquidity in the market**

Synthetic Securitisation

- Synthetic securitisation does not involve “real” lending.
- However, it affects the cost of “real” lending.
  - How?
- **Ultimately, consumers and companies have cheaper access to credit,**
  - **Synthetic securitisation increases the liquidity in the market**
- Securitization massively pumped money into the economy (before 2008).
- Were central banks on top of this new liquidity source?

Pre-Summer ‘07

- Early 2000s : Negative (or very close to negative) real interest rates
- Financial institutions’ incentives:
  - Borrow money
  - Lend it to consumers and corporations
- Securitisation allowed banks to outsource, from their balance sheets, the risks derived from their lending activities
- Banks were able to recycle and reuse their credit lines more freely
- “Originators” and “Structurers” were keen on securitising assets, and investors were keen on buying the final assets. This process generated a “wall of money” being thrown into companies and individuals.
- **Securitisation compounded the impact of a loose monetary policy regime by providing the economy with extra liquidity**

Musical Chairs Game

- Self-reinforcing process
  - Improving economic fundamentals
  - Easy monetary policy
  - Bank lending
  - Risk outsourcing
  - Securitisation and synthetic credit issuance
- Result: spread compression from 2003 to 2007
- Risk of the process:
  - Sudden disruption of any of its components, which brings the rest to an end
- **Summer 2007: securitisation stops and liquidity vanishes**

2007/8 – Game Over

- Process of increasing liquidity/improving credit quality was halted

- **Trigger events**:
  - Concerns on the US mortgage market
  - Potential spill over into the broader economy
  - The “subprime problem” just unveiled the risks for the economy derived from years of debt accumulation by American consumers

- Securitisation slows down dramatically
  - Initially in the **mortgage** and asset backed markets
  - **Speculation** about exposure of investment banks, commercial banks and other institutions to the mortgage market
  - Liquidity in the **interbank market** dries up
  - Market participants who were over-relying on **short-term liquidity** started having serious problems (e.g. SIVs, Northern Rock…).

Market Sell-Off

- Central banks hurried to intervene through **emergency liquidity operations**

- **Fears** that the liquidity problems could turn into a credit crunch, caused a general sell-off in credit markets
  - Investors **rush to hedge** their credit portfolios

- Consensus at the time (July/August 2007):
  - “Transitory” increase in spread levels due to the market turbulence not to the risk of any default. “Fundamentals remain strong.”

- Preferred hedging instruments: cheapest ones & subject to “systemic/correlated” risk
  - Financial credits
  - Highly rated tranches…

- **“Flight-from-quality”**: increased perceived credit risk of the “safest” instruments
  - Spreads in financial credits widen above those of corporate credits

Ratings-Based Investment Culture

- 2007/2008: Huge volatility on the mark-to-market of highly rated (AAA/AA) products
  - Structured products (e.g. AAA tranches of mortgage CDOs, loan CDOs …)
  - Credit derivatives (e.g. AAA synthetic corporate tranches)
  - Bank spreads

- Rating agencies jump to the spotlight
- Investors and regulators question soundness of the rating process

- The market realises its **dependence on ratings is "too big … to fail"**
  - Investment decisions/limits are set as a function of ratings
  - Central bank regulations rely on ratings

2008/9 – The Old Rules Are Not Valid

- **Confidence on the most widely used risk metrics vanishes**
  - Uncertainty about the true risks in the credit market soars
  - For flexible investors, dislocations were plentiful
  - Hedge fund returns grow hand in hand with the confusion of market players

- Worries about potential unwinds of the AAA positions of SIVs
- Main concern in the credit markets is still spread widening rather than defaults
- The dislocations in the credit markets persist as the “CDO-bid”, once a spread shock-absorber, vanishes

- **The market dries up**

Appendix A-1

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