Minimum Capital Requirements for Market Risk* - Internal Models Approach

Desk-Level Eligibility

*** also known as Fundamental Review of the Trading Book**

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Desk Level session
Risk Incisive Training on FRTB
London, 22-23 March 2016

http://www.training.risk.net/digital_assets/19222/FRTB_2016_Complete.pdf

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Outlines

- References
- Overview of Market Risk Capitalisation: current and FRTB
- Journey to IMA waiver by desk
  - P&L attribution test: Hypothetical and Risk-theoretical P&Ls
  - Modellability criteria
  - Backtesting
- Capitalisation: varying liquidity horizons, reduced sets, limited diversifications
- Discussions

References

Basel

- Standards: Minimum capital requirements for market risk, Jan 2016
  https://www.bis.org/bcbs/publ/d352.pdf
- Basel III monitoring, aka QIS.
  - July 2015 version for P&L Attributions
  - On-going
    https://www.bis.org/bcbs/qis/

Related Materials

- Flooded with *things* (including this one!) on FRTB
  consultants, conferences, jobs, ££s, etc
- ISDA impact analysis
  https://www2.isda.org/functional-areas/risk-management/

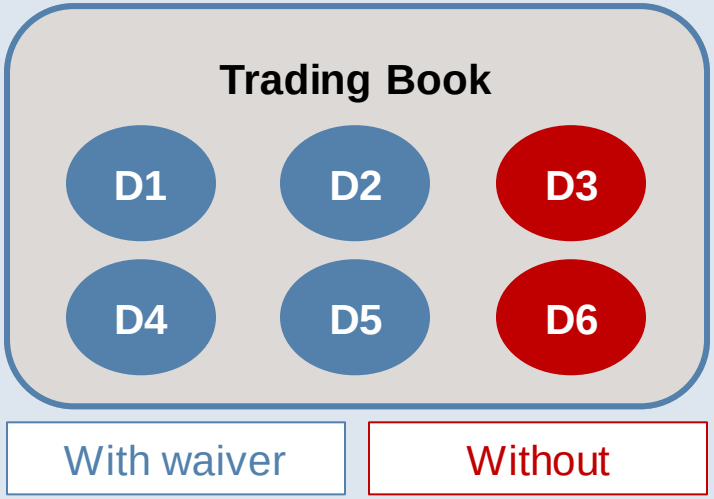
Market Risk Capitalisation

1. Market risk capitalisations
   - Organise trading book into desks
   - Internal models waiver by desk
     - P&L attribution and backtesting
     - Securitisation: SA only
   - Calculate capital

Inside the waiver	Outside the waiver
Internal models approach i.e. ES, DRC, NMRF	**Standardised Approach** • non-default charge: SBA • default charge • residual risk add-on

2. Interaction between IMA and SA
   - *"…the standardised approach … a floor to, the IMA…"*
   - *"..calculate the standardised capital charge for each trading desk as if it were a standalone regulatory portfolio."*

For capitals



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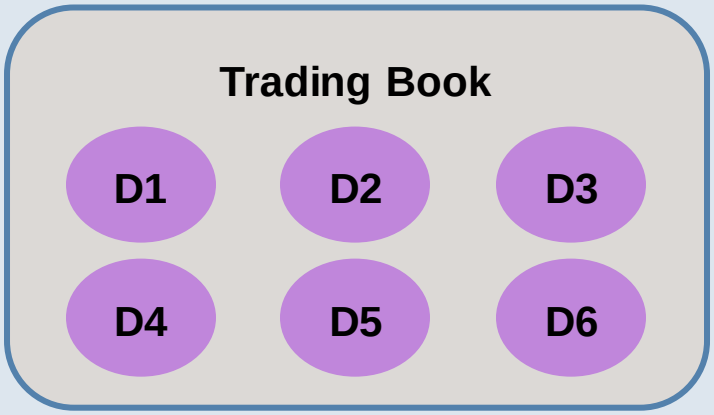
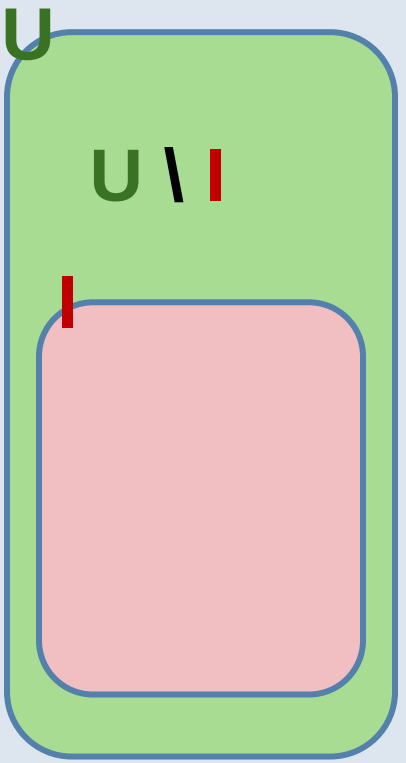


All positions under SA

IMA Waiver - P&L Attribution (1/3)

P&L Attribution Test

"… to identify whether a bank's trading desk risk management model includes a sufficient number of the risk factors that drive the trading desk's daily P&L."



How does it work? For each desk,

1. Calculate daily hypothetical P&Ls
   a) Let **U** be the set of risk factors used in the bank's official P&Ls
   b) Re-value the positions held at the end of the previous day (t_n) using the market data at the end of the current day (t_{n+1})

$$P\&L^{HYPO} = V^{FO}(\ \mathbf{U}_{n+1}\ ;\ Pos_n) - V^{FO}(\ \mathbf{U}_n\ ;\ Pos_n\ )$$

2. Calculate daily risk-theoretical P&Ls
   a) Let **I** be the set of risk factors to be included in IMA (i.e. risk management model).
   b) **I** is a *subset* of **U** (potentially the same)
   c) Re-value the positions held at the end of the previous day using the market data conditional on risk factors in **I** at the end of the current day. Roughly, speaking...

$$P\&L^{RISK} = V^{RISK}(\ \mathbf{I}_{n+1}\ ,\ (\mathbf{U} \setminus \mathbf{I})_n\ ;\ Pos_n) - V^{RISK}(\ \mathbf{I}_n\ ,\ (\mathbf{U} \setminus \mathbf{I})_n;\ Pos_n\ )$$

3. Test Measures: Check whether they are close to each other. (..later..)

IMA Waiver - P&L Attribution (2/3)

Remarks

1. **Unofficially**, the final text on PLA has been reverted back to the old text (see July 2015 QIS version)
2. Risk-theoretical P&L:
   - The daily desk-level P&L that is predicted by the risk management model conditional on a realisation of all relevant risk factors that enter the model (glossary)
   - The calculation of the risk-theoretical P&L should be based on the pricing models embedded in the firm's ES model and not front office pricing systems (2015 QIS)
3. Important is the consistency in **market data** and **pricers** between FO & Risk
4. Key Output: The set of risk factors capitalised through in IMA
   - Why's important (why am I repeating)?
   - Specific to each of individual banks
   - example: Is the 3v6 tenor basis relevant?
     - Probably no, if the bank is always on directional on swap contracts.
     - Probably yes, if the bank has offsetting contracts between 3Ms and 6Ms.
   - Outside this set, nothing to worry. Even out of scope for NMRF charges
5. Unclear (but likely included in): model parameters such as mean-reversion rate (valuation adjustments)

IMA Waiver - P&L Attribution (3/3)

Test Metrics

- To pass the test, the unexplained daily P&Ls should be 'small'.

$$P\&L^{UN} = P\&L^{HYPO} - P\&L^{RISK}$$

- Monthly check the following two conditions

mean ratio	variance ratio
$\left\lvert \frac{\text{mean}(P\&L^{UN})}{\text{std}(P\&L^{HYPO})} \right\rvert < 0.1$	$\left\lvert \frac{\text{std}(P\&L^{UN})}{\text{std}(P\&L^{HYPO})} \right\rvert^2 < 0.2$

- Fail if 4 or more breaches within the prior 12 months.

Challenges

- variance ratio < 0.2 means 90% correlation between HYPO and Risk P&Ls
  (assuming normal distributions with the same variance size)

- well-hedged desks may potentially make any residual risks material. So, *potentially*, difficult to pass.

P&L Attribution Test: Data Mis-Alignment (1/2)
very simple 'desk' example (FX spot)

Hypothetical P&Ls

- functional/reporting currency: USD
- position: GBP 1000 cash
- official valuation using London-close market data
- V^{FO} = 1000 x GBPUSD(London)

Risk-theoretical P&Ls

- risk models using NY-close market data
- V^{Risk} = 1000 x GBPUSD(NY)

Date	Close	GBPUSD	V (FO)	Hypo P&L	V (RISK)	Risk P&L
...	...	...	...	...	...	...
-3	Tokyo	1.500				
	London	1.516	1515.6	**36.5**		
	New York	1.489			1489.4	**15.9**
-2	Tokyo	1.529				
	London	1.552	1552.0	**-12.3**		
	New York	1.505			1505.3	**52.7**
-1	Tokyo	1.560				
	London	1.540	1539.8	**-33.2**		
	New York	1.558			1558.0	**-26.1**
0	Tokyo	1.527				
	London	1.507	1506.6			
	New York	1.532			1531.9	

- In this example, the test is to compare (36,5,-12.3,-33.2, ...) vs (15.9, 52.7, -26.1, ...).
- likely... pass or fail?

P&L Attribution Test: P&L Mis-Alignment (2/2) very simple 'desk' example (FX spot)

Example of mixing market data from FO and risk systems

- *Shifts* (from t_n to t_{n+1}) of risk factors in risk system are applied to FO risk factor of t_n

Date	Close	GBPUSD	V (FO)	Hypo P&L	RISK & FO		V (RISK)	Risk P&L
...	...	...	...	...	shift	new level	...	...
-3	Tokyo	1.500						
	London	1.516	1515.6	**36.5**				**16.2**
	New York	1.489			1.011			
-2	Tokyo	1.529						
	London	1.552	1552.0	**-12.3**		1.532	1531.7	**54.4**
	New York	1.505			1.035			
-1	Tokyo	1.560						
	London	1.540	1539.8	**-33.2**		1.606	1606.4	**-25.8**
	New York	1.558			0.983			
0	Tokyo	1.527						
	London	1.507	1506.6			1.514	1514.0	
	New York	1.532						

- Potentially, for banks using sensitivity-based VaRs

$$\text{P\&L}^{\text{RISK}} = \text{Delta}^{\text{FO}} \times (X_{n+1}^{\text{RISK}} - X_n^{\text{RISK}})$$

- sensitivities from FO
- risk factor shifts are from risk system

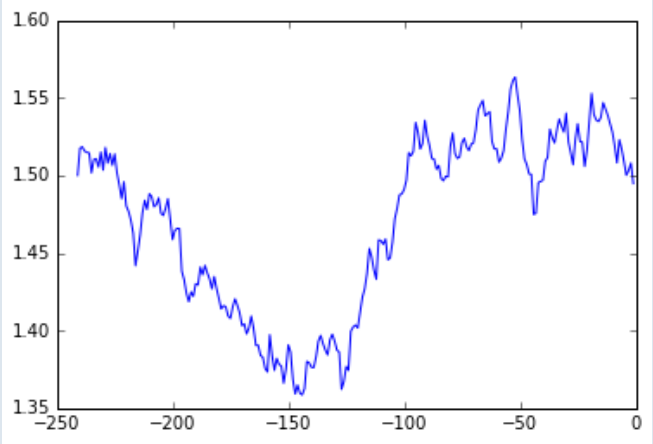
Likely, P&L attribution test to fail!

P&L Attribution Test: Deciding Materiality (0/3)
other simple 'desk' examples (FX option)

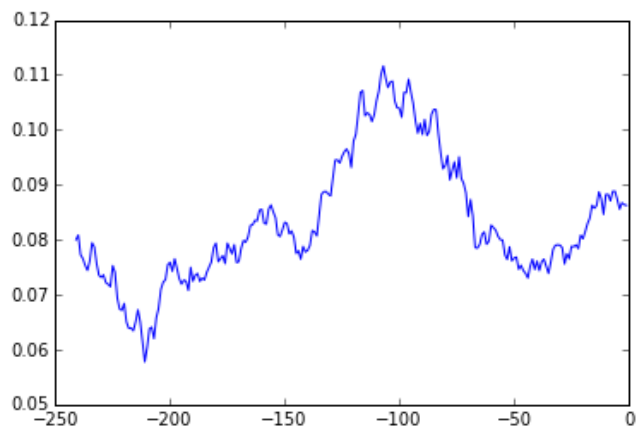
- Following experiments are considered

			Official (FO)		Risk Management	
	Desk	**Portfolio**	**Pricer**	**Market Data**	**Pricer**	**Market Data**
1	Naked	• ATM FX option	BS	Spot & Implied Vol	BS	Spot
2	Delta Hedged	• ATM FX option • Linear delta-hedging trade			BS	Spot
3					1st order Approx	Spot & Implied Vol

- Simulation: FX spot



FX ATM vol



risk factor	model	initial value	volatility
spot	GBM	1.5	0.1
atm vol	BM	0.08	0.03

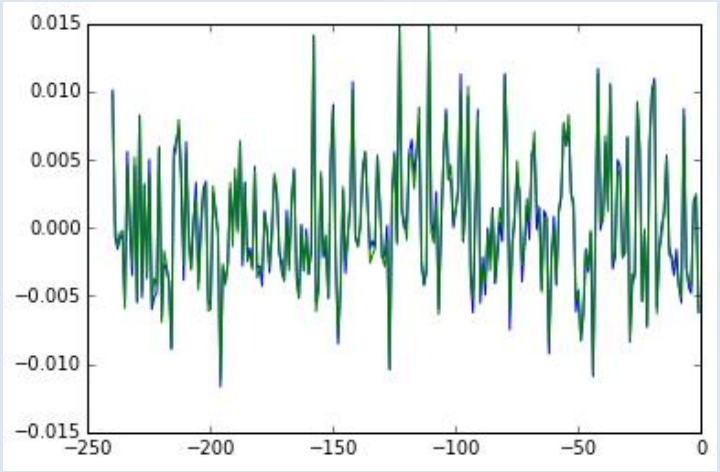
P&L Attribution Test: Deciding Materiality (1/3)
other simple 'desk' examples (FX option)

Experiment 1

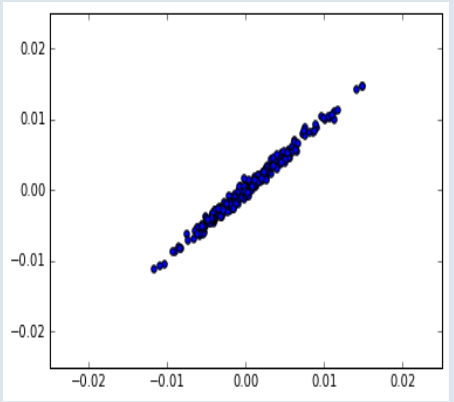
- Portfolio of naked FX option
- Risk management system
  - pricer: Black-Scholes (as as FO)
  - market data: spot only, no implied vol

- P&L Attribution Test
  - pass!
  - For this desk, the implied volatility is <u>not a material</u> risk factor.
  - Consequently, <u>no</u> IMA capital charge due to this risk factor.

- Hypo P&Ls vs Risk P&Ls time series



- Hypo P&Ls vs Risk P&Ls scatters



Metric 1	Metric 2
4%	1%
3%	2%
1%	1%
3%	3%
2%	1%
4%	1%
3%	2%
4%	2%
4%	3%
1%	1%
2%	1%
2%	1%

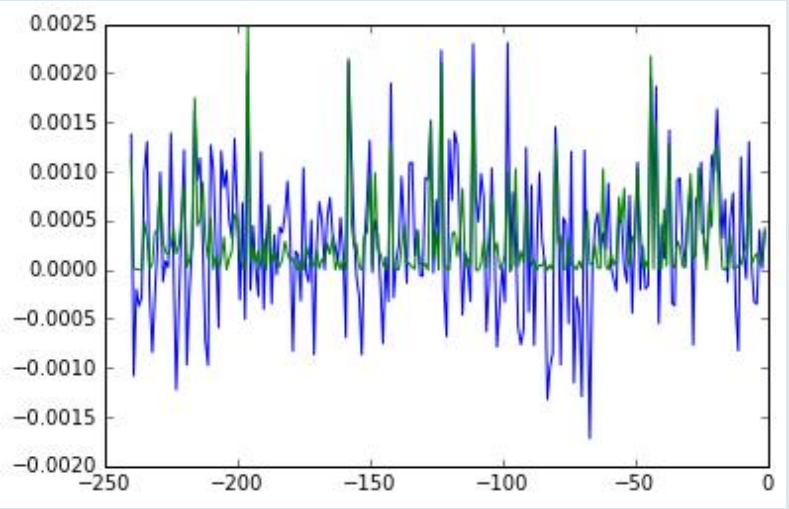
P&L Attribution Test: Deciding Materiality (2/3)
other simple 'desk' examples (FX option)

Experiment 2

- Portfolio of delta-hedged FX option
- Risk management system
  - pricer: Black-Scholes (as as FO)
  - market data: spot only, no implied vol

- P&L Attribution Test
  - fail!
  - To pass the test, the implied volatility must be included in the risk P&Ls.
  - For this delta-hedged desk, the implied volatility is a material risk factor and shall be included in IMA capital charge.

- Hypo P&Ls vs Risk P&Ls time series



- Metrics

Metric 1	Metric 2
25%	63%
15%	75%
8%	62%
20%	106%
13%	28%
31%	48%
19%	79%
19%	71%
23%	89%
11%	45%
17%	68%
13%	59%

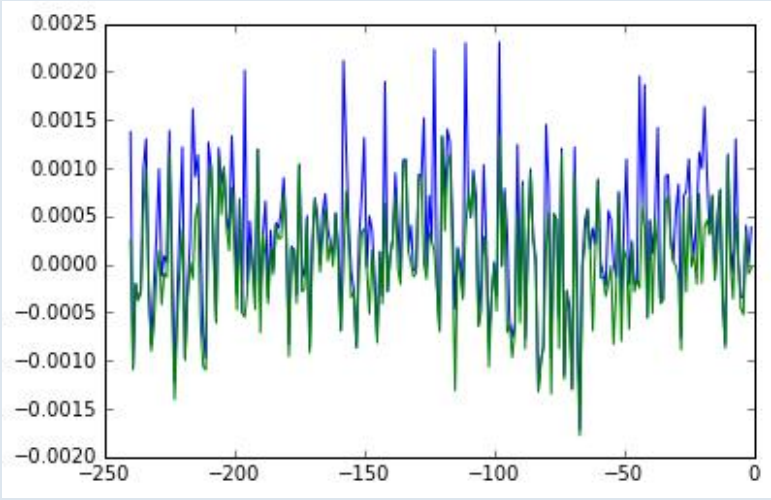
P&L Attribution Test: Deciding Materiality (3/3)
other simple 'desk' examples (FX option)

Experiment 3

- Portfolio of delta-hedged FX option
- Risk management system
  - pricer: 1st-order approximation (both spot and vega)
  - market data: spot & implied vol

- P&L Attribution Test
  - fail!
  - To pass the test, the pricer embedded in the risk system should be improved.
  - High-order terms (Gamma and/or curvatures) should be incorporated in the pricer

- Hypo P&Ls vs Risk P&Ls time series



- Metrics

Metric 1	Metric 2
39%	14%
45%	27%
46%	82%
22%	4%
48%	45%
41%	64%
39%	33%
22%	13%
28%	17%
62%	70%
67%	48%
45%	35%

IMA Waiver - Modellable or NonModellable?

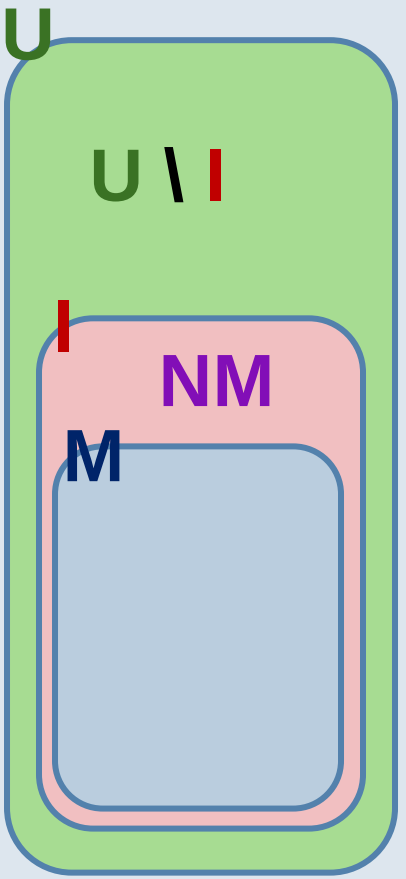
Determining Modellable Risk Factors

1. The risk factor modellability analysis is for those included as part of P&L Attribution tests, i.e. **I**.

2. A risk factor is modellable if
   - There are at least 24 observable real prices per year
   - A maximum period of one month between two consecutive observations
   - Combination of modellable risk factors

   Otherwise, it is non-modellable.

3. A price is <u>real</u> if there is an evidence of actual transactions behind
   - At which the bank has conducted a transaction
   - Verifiable price for an actual transaction between other arms-length parties
   - Obtained from a committed quote
   - Obtained from a 3rd party vendor

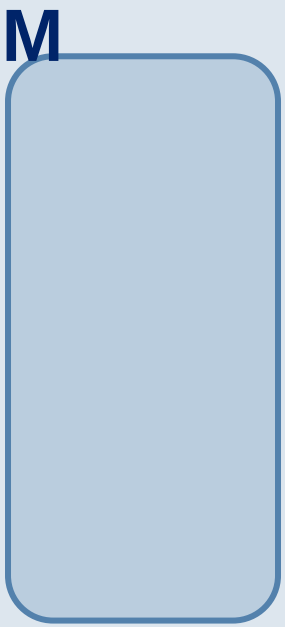


IMA Waiver - Internal Modelling and Backtesting (1/2)

Hang on!
Thought varying liquidity horizons?
Stay tuned…

Risk Factor Modelling

- Modellable risk factors are eligible for being included in the internal models
- The data used for actual modelling can be different from the data used to determine the modellability (room for back-filling, proxy, regression, etc)
- Jointly simulate to generate a set of scenarios over one of the following horizons
  - 1-day: for back-testing
  - 10-days: for capitalisation



Backtesting

- Similar to the current rule
  - Comparisons:

1-day VaR vs	1-day Hypo P&L
	1-day Actual P&L

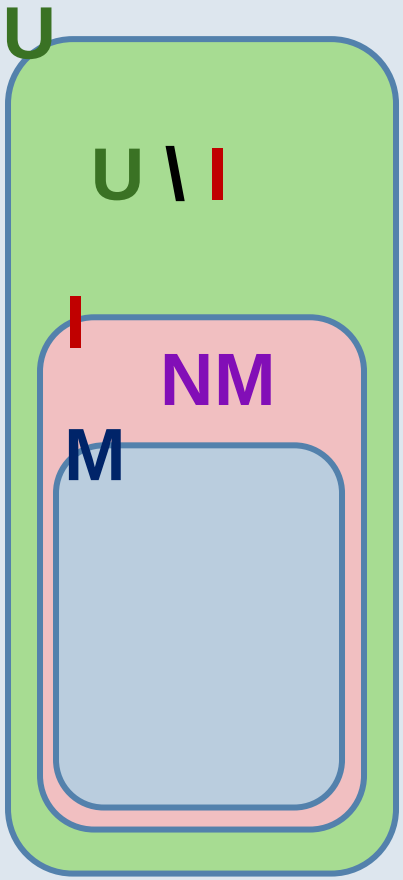
  - Yes, VaR not ES.
  - Exception counts over one year at two percentiles:
    - up to 12 for 99th & up to 30 for 97.5th
- If pass this test, we FINALLY have a waiver on the desk.
- A multiplier is determined based on the number of exceptions: starting from 1.5 to 2

IMA Waiver - Internal Modelling and Backtesting (2/2)

Why Back-testing Would Fail?

1. Insufficient modellable risk factors
   - 1-day PNL is computed with ALL risk factors included.
   - Exceptions due to non-modellable risk factors may be disregarded

2. Model is not conservative enough
   - Back-testing is really about the conservatism of the internal model.



P&L Attribution and Backtesting

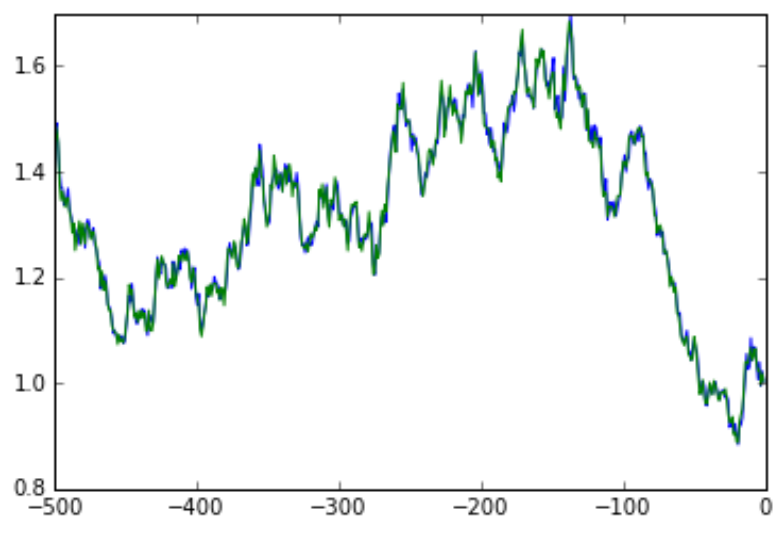
- P&L Attribution
  - determination of the set of risk factors capitalised under IMA framework
  - Both modellable and non-modellable risk factors

- Backtesting: appropriateness of modelling of modellable risk factors eligible for ES measures
  - appropriateness of modelling of modellable risk factors eligible for ES measures
  - Non-modellable risk factors: so-called SES charges like RNIVs
- More to come later

P&L Attributions vs Backtesting (1/2)
experiments with the simple 'desk' example

Settings

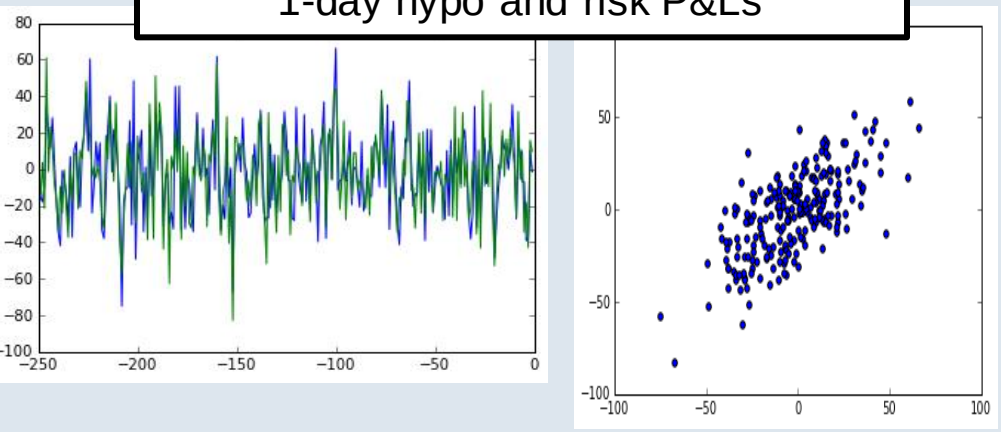
- Desk with GBP1000 cash and reporting currency USD
- Assume the official close for the desk is London close
- Risk factor: GBPUSD FX spot
- Experiment: simulate FX spot rates for London and New York closes
- Geometry Brownian Motion: d X / X = σ dW with σ = 30% / annum



P&L Attributions vs Backtesting (2/2)
experiments with the simple 'desk' example

- Suppose that Risk P&Ls are based on New York closes (instead London, our official closes)
- Hypo P&Ls vs Risk P&Ls over 1 year

1-day hypo and risk P&Ls

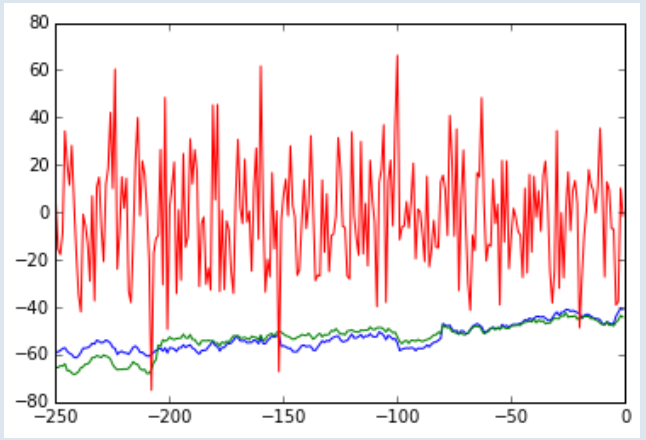


- P&L Attribution test fails!

mth	1	2	3	4	5	6	7	8	9	10	11	12
ratio	50%	67%	75%	59%	29%	151%	34%	63%	47%	85%	119%	40%

But, this does not necessarily mean that the VaR/ES models are bad.

- Consider historical VaR



hypo P&L, VaR using London-closes and VaR using New York-closes

- Only 3 exceptions using either time series.
- Pass Backtesting!

P&L attribution test and backtesting are really two different things!

Capitalisation under IMA Framework - Overview

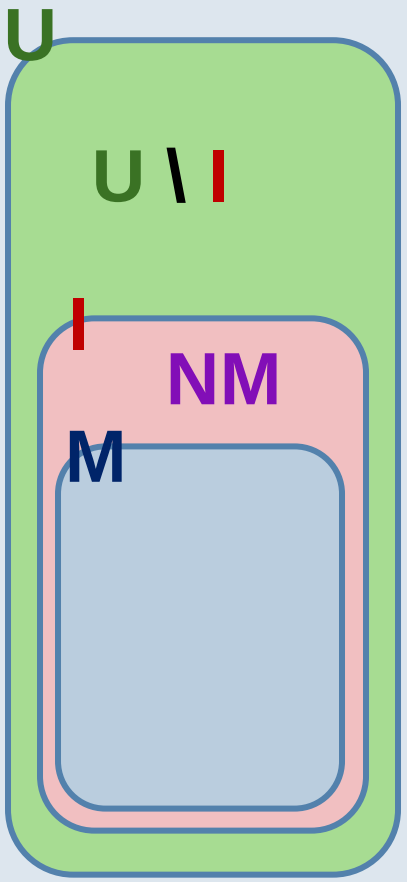
Non-Default Risk Charges

1. Base on the risk factors in **I**, those identified through P&L attribution test.
2. Market risk from modellable risk factors in **M**
   - Expected shortfall with varying liquidity horizons
   - Current and stressed ESs are combined
   - With limited diversification effects between asset classes
3. Market risk from non-modellable risk factors in **NM**
   - Similar to RNIVs
   - Based on stress scenario
   - No diversifications across risk factors (i.e. straight sum)
   - Except: zero-correlation assumption (i.e. sqrt of sum of squares) is allowed for idiosyncratic risk factors.

Default Risk Charges (DRC)

- Default only. No migrations
- 2-factor models
- PD/LGDs from banking book

No Charges for U \ I, i.e. not material risk factors



No CRM equivalent

No Securitisations

Capitalisation of MRF; Liquidity Horizons for Expected Shortfalls

Liquidity Horizons

Risk factor category	*n*
Interest rate: specified currencies – EUR, USD, GBP, AUD, JPY, SEK, CAD and domestic currency of a bank	10
Interest rate: – unspecified currencies	20
Interest rate: volatility	60
Interest rate: other types	60
Credit spread: sovereign (IG)	20
Credit spread: sovereign (HY)	40
Credit spread: corporate (IG)	40
Credit spread: corporate (HY)	60
Credit spread: volatility	120
Credit spread: other types	120
Equity price (large cap)	10
Equity price (small cap)	20
Equity price (large cap): volatility	20
Equity price (small cap): volatility	60
Equity: other types	60
FX rate: specified currency pairs[37]	10
FX rate: currency pairs	20
FX: volatility	40
FX: other types	40
Energy and carbon emissions trading price	20
Precious metals and non-ferrous metals price	20
Other commodities price	60
Energy and carbon emissions trading price: volatility	60
Precious metals and non-ferrous metals price: volatility	60
Other commodities price: volatility	120
Commodity: other types	120

From page 55

Capitalisation of MRF : Incorporating Varying Liquidity Horizons

Myth: It is required to simulate over various liquidity horizons beyond 10-days.

ES Calculation with multiple liquidity horizons

$$ES = \sqrt{\left(\mathrm{ES}_T\left(P\right)\right)^2 + \sum_{j\geq 2}\left(\mathrm{ES}_T\left(P, j\right)\sqrt{\frac{\left(LH_j - LH_{j-1}\right)}{T}}\right)^2}$$

j	LH_j
1	10
2	20
3	40
4	60
5	120

- *T :* base horizon, i.e. 10 days;
- *P:* Portfolio
- $ES_T(P)$ is ES at horizon *T* with shocks to all risk factors
- $ES_T(P, j)$ is ES at horizon *T* with shocks to the risk factors with liquidity horizon at least LH_j. Others held constant.

Capitalisation of MRF: Stressed Expected Shortfall

No two versions: always calculate stressed version

(stressed) ES Calculation:

$$ES = ES_{R,S} \cdot \frac{ES_{F,C}}{ES_{R,C}}$$

$ES_{x,y}$

x	risk factor set
F	Full
R	Reduced

y	calibration period
C	Current (last 12M)
S	Stressed

- Reduced set of risk factors:
  - explain a minimum of 75% of the variation of the full ES model
  - How?!?

Capitalisation of MRF: Final ES Charge

Capital Charges for Modellable Risk Factor

$$IMCC = \rho\left(IMCC\left(C\right)\right) + \left(1-\rho\right)\left(\sum_{i=1}^{R} IMCC\left(C_i\right)\right)$$

$$\text{where } IMCC\left(C\right) = ES_{R,S} \times \frac{ES_{F,C}}{ES_{R,C}} \text{ and } IMCC\left(C_i\right) = ES_{R,S,i} \times \frac{ES_{F,C,i}}{ES_{R,C,i}}$$

- *i*: risk classes, one of IR, EQ, FX, Commodity, Credit spreads
- ρ: diversification parameter across risk classes (set to 0.5)

Capitalisation of MRF: Calculation Counts

Increased Calculation Counts

- 5 risk classes and cross-set: 6 total
- 3 combinations of risk factors and periods: (R,S), (R,C) and (F,C)
- 5 different liquidity horizons

Without any optimization, 6 x 3 x 5 = 90 ES calculations required!

Capitalisation: Non-Modellable Risk Factors

Capital Charges for Non-Modellable Risk Factor

$$SES = \sqrt{\sum_{i=1}^{L} ISES_{NM,i}^2} + \sum_{j=1}^{K} SES_{NM,j}$$

- $ISES_{NM,i}$ is the stress scenario capital charge for idiosyncratic credit spread non-modellable
- $SES_{NM,j}$ is the stress scenario capital charge for non-idiosyncratic risk factor

Q: What about idiosyncratic equity risk factors?

Capitalisation of Default Risk Charge

DRC

- To capitalise the default risk of trading book
  - Over one-year at 99.9th percentile (as IRC)
  - What about migration risks?
  - Long liquidity horizons (up to 6 months) for credit spread risk as part of ES

- Key requirements
  - Removed the concept of *constant level of risk*.
  - Default simulation models with two types of systematic risk factors
  - Correlations based on credit spreads or equity prices
  - Scope includes sovereign bonds, equity, defaulted debts as well.
  - Capture various risks (maturity mismatch, concentrations, non-linear behaviour, etc)
  - Reflect the economic cycle in recovery rates
  - Waiver for both spread risk & default risk together!
  - Re-use of PDs and LGDs from banking book

Final Charges

Approved Desks: IMA

- ES: modellable risk factors
- SES: non-modellable risk factors
- DRC: default risk

Unapproved Desks: Standardised Approach

- Delta/Curvature/Gamma charges
- Default charges
- Residual Risk Add-on

Discussions

Internal decisions on IMA eligible desks

Data and pricing alignments

How to handle idiosyncratic positions: P&L attribution tests and modellability tests

Appendix: What is FRTB?

In One Sentence

- *"… revised standards for minimum capital requirements for Market Risk …"*

Key Revisions:

- Internal Models-Approach (IMA)

  ES, varying liquidity horizons, P&L attribution, non-modellable risk, desk-level approvals, DRC, …
- Standardised Approach (SA)

  sensitivity-based approach, securitisations, default charges

- *Regulatory* Trading Book
  - Reducing arbitrage between banking and trading books
  - Scope
    - default, IR, credit spread, EQ, FX, commodities for trading book
    - FX and commodities for banking book