GoldenSource

A data-centric view of liquidity in market risk and valuations

Liquidity concepts in trading book controls and other banking regulation: FRTB, prudential valuations, bid-ask reserving, fair value hierarchy

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Contents

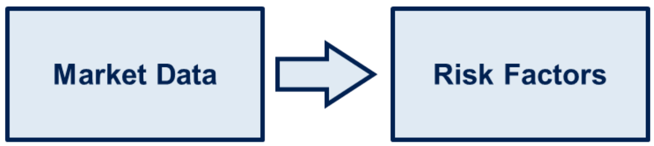
1. Introduction

The measurement, monitoring and adjustment for liquidity is a central part of finance and market risk processes for a bank's trading book. Section 2 of this paper describes the background to some of these finance and market risk processes. Section 3 (IPV and Valuations) and Section 4 (Market Risk) reviews the data requirements for valuations and market risk processes. Section 5 then looks specifically at liquidity and describes how what seem like very different regulations and trading book controls are in fact addressing the same underlying issue: accounting for the varying liquidity of the under markets in which financial instruments are traded.

2. Background

2.1. Market data requirements for Finance and Market Risk

Market data (both daily and time-series) is an essential element in the production of P&L and risk numbers in firms that are subject to market risk regulatory capital requirements and specifically to those that will need to comply with FRTB. Market data is required to answer all 5 of the key questions that a trading firm needs to answer on a daily basis.



5 Questions for P&L and Market Risk instruments

Today's P&L rates ok?
Can I see explain the impact of changes in market rates on today's P&L and valuations?

Historical rates ok?
Can I see the time-series & associated validation status for the instrument?

Analytics & Quant Development?
Can I use the validated data to perform analytics & do quantitative development

Is instrument Modellable?
Do I have sufficient real price observations?

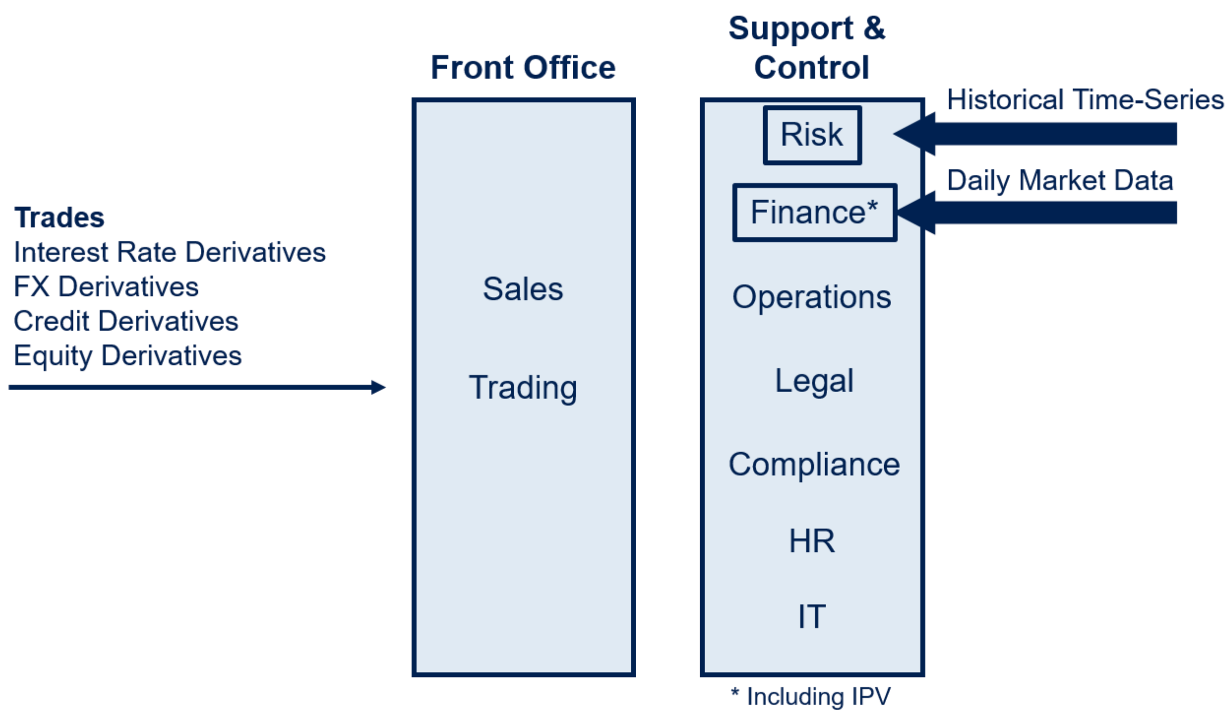
Materiality?
Do I have exposures in the instrument?

2.2. Team functions within the trading book

The interaction between valuations-related teams and market risk teams is a topic that is of central importance for FRTB and for more generally for the efficient operation of the bank's trading function.

The valuations-related teams, for example, IPV, PRUVAL, and Product Control typically sit within the wider Finance function. Product Control are responsible for approving the P&L numbers that result from daily changes in valuations. IPV stands for Independent Price Verification and they are responsible for the verification of the prices used by the trading function. PRUVAL is the prudential valuations team. They are responsible for calculating the adjustments required for regulatory risk buffer required for prudential valuations.

The Market Risk Team sits within the wider risk function. They are responsible for calculating risk measures such as value-at-risk and expected shortfall as ensuring trading desks stay within their risk limits. The Trading and the Quantitative Research teams are part of the Front Office.

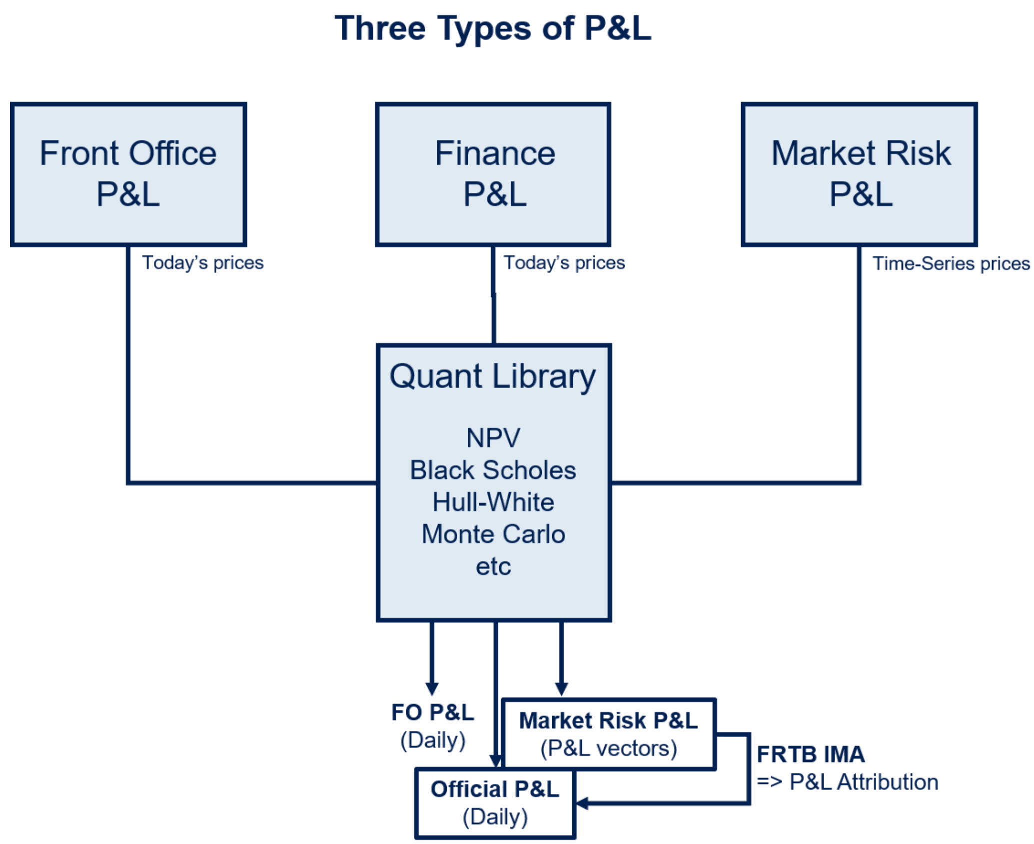


The use of a common database of market data across Finance, Risk and Front office is a basic principle of EDM (Enterprise Data Management) for a trading firm. At its most basic, market data is required to generate valuations (and therefore P&L) and nothing more. Changes in market data over the course of either a day or over a historical time-frame (e.g. a Liquidity Horizon) creates the P&L that the trading function is ultimately striving to produce and report as accurately as possible. One way to think of this is to think about P&L coming in three forms:

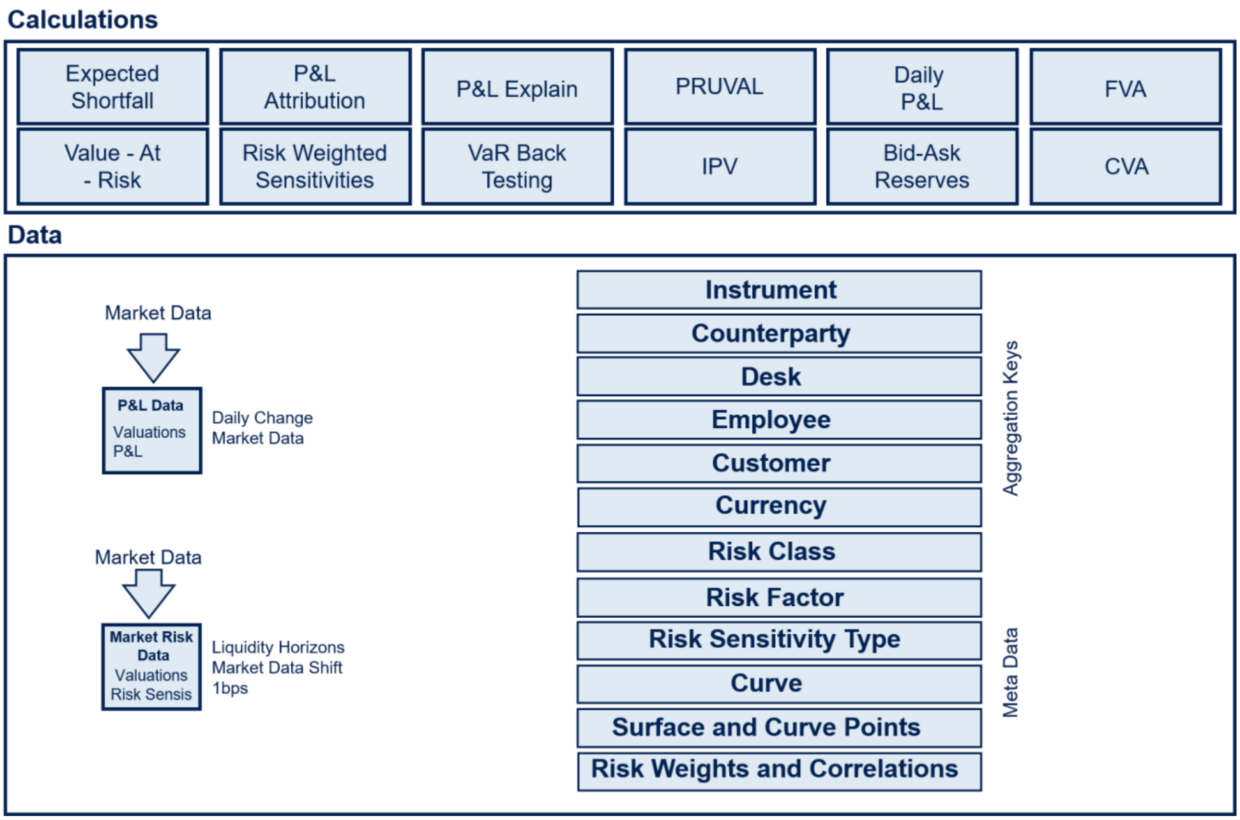
- Front Office P&L => Daily changes in front office rates
- Finance P&L => Daily changes in Finance approved rates
- Market Risk P&L => Changes in rates over a specific time-horizon[1]

The diagram below illustrates the concept.

[1] FRTB refers to these historical time horizons as liquidity horizons



One of the key objectives of FRTB is to ensure that these different categories of P&L are produced in broadly the same way and that any differences between the approaches can be explained. One of the tests that a trading desk needs to be able to pass in order to be allowed use the FRTB Internal Models Approach (IMA) is the P&L Attribution test. The broad objective of this test is to make sure that P&L that is produced for official reporting uses models, data and approaches that are consistent with the models, data and approaches that are required to produce market risk regulatory capital numbers under IMA. To achieve this objective it is essential that both the Valuations teams that sit in Finance and the Market Risk teams are using the same consolidated data stores. The design of relationships between the data stores that exist across Valuations and Market Risk teams will be central to the success of the coordinated approach that regulations such as FRTB demand. If the data stores underlying Finance and Market Risk are aligned and adhere to a robust set of data modelling and lineage principles then the calculations become straight forward. Data and data alignment is 80% of the work. The diagram below illustrates the concept.



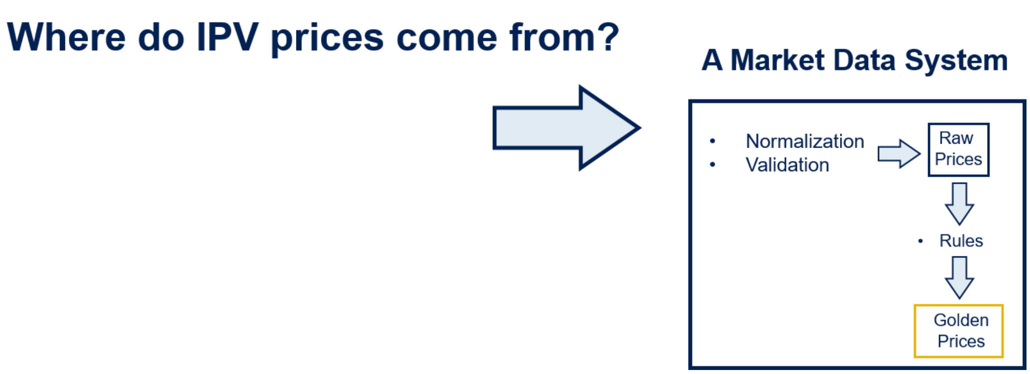
Calculations
Expected Shortfall
P&L Attribution
P&L Explain
PRUVAL
Daily P&L
FVA
Value - At - Risk
Risk Weighted Sensitivities
VaR Back Testing
IPV
Bid-Ask Reserves
CVA
Data
Market Data
P&L Data
Valuations
P&L
Daily Change
Market Data
Market Data
Market Risk Data
Valuations
Risk Sensis
Liquidity Horizons
Market Data Shift
1bps
Instrument
Counterparty
Desk
Employee
Customer
Currency
Risk Class
Risk Factor
Risk Sensitivity Type
Curve
Surface and Curve Points
Risk Weights and Correlations
Aggregation Keys
Meta Data

3. IPV and Valuations

IPV stands for Independent Price Verification. The primary purpose of an IPV team is to ensure that the rates and prices that a Trading Desk uses to generate its version the desk's valuations and P&L are independently verified. One of the main tasks that an IPV function is check the validity of the prices that are used by traders to generate their Front Office P&L:

Front Office prices need to be tested. They can come from multiple sources:

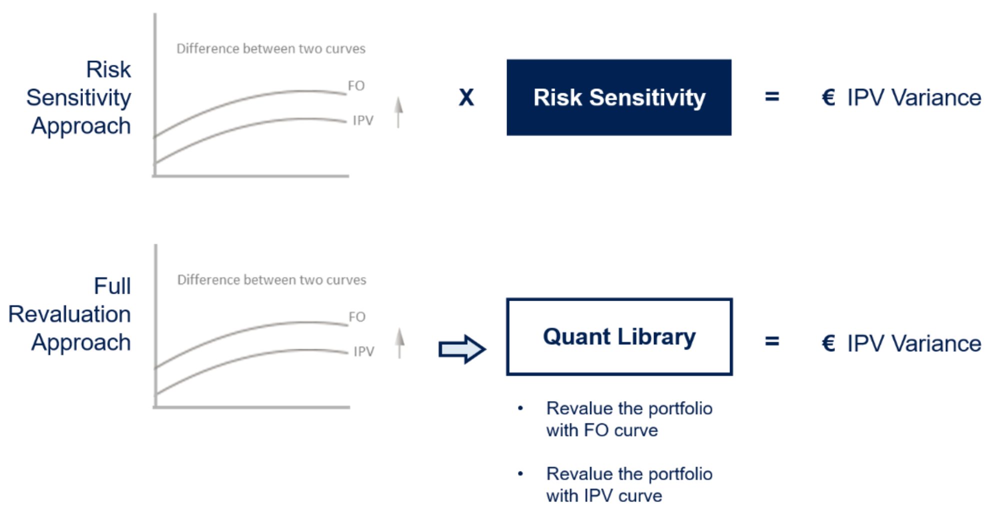
Front Office prices are usually tested by comparing them to independently sourced prices. In our FRTB eco-system, these independent prices are sourced from vendors / other locations, normalized, validated and stored centrally in a Market Data System:



Differences between Front Office and IPV rates lead to a need to make an adjustment to Front Office valuations. These types of adjustment are called IPV Variances. When producing IPV variances for derivative positions, two types of approaches are possible:

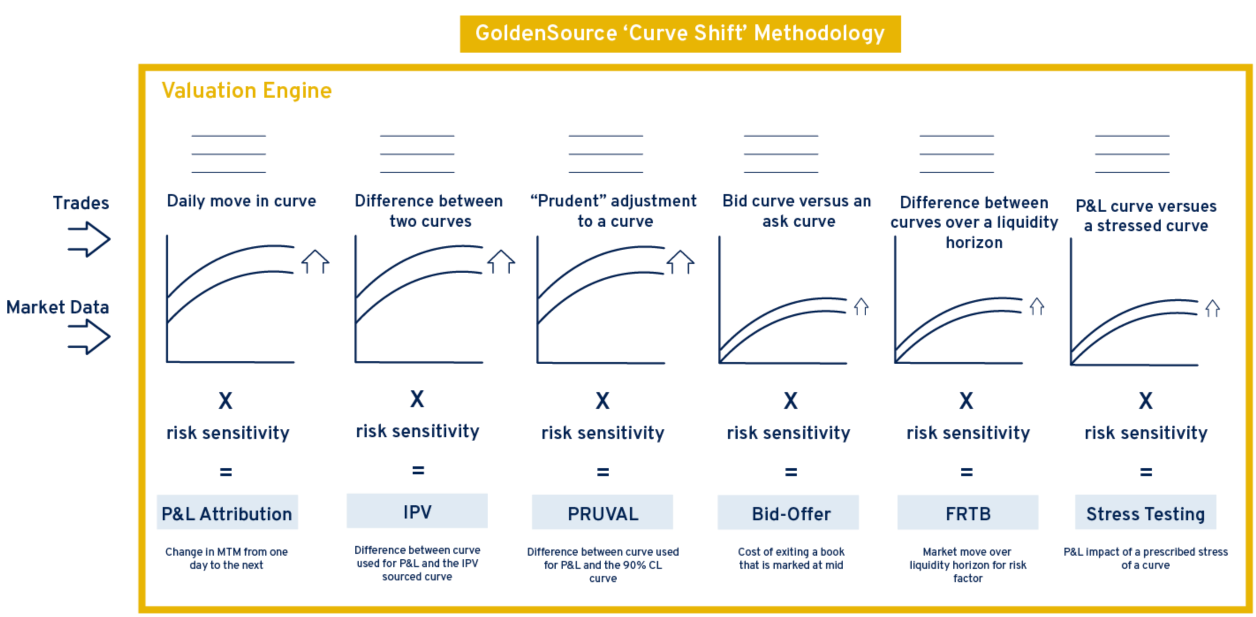
- A risk sensitivity approach
- A full revaluation approach

Two approaches to calculating IVP variance



Most Finance and Market Risk calculations (including IPV variances) can be calculated using either approach.

Risk sensitivities are typically produced by the bank's Quant Library by shifting curves or other risk factors by a standardized market data amount (e.g. a basis point). The risk sensitivity is the difference between the valuation produced before the risk factor shift and the valuation produced after the risk factor shift. The diagram below describes Curve Shift Approaches showing how risk sensitivities can be used to generate the P&L & Market Risk charges including IPV Variances.

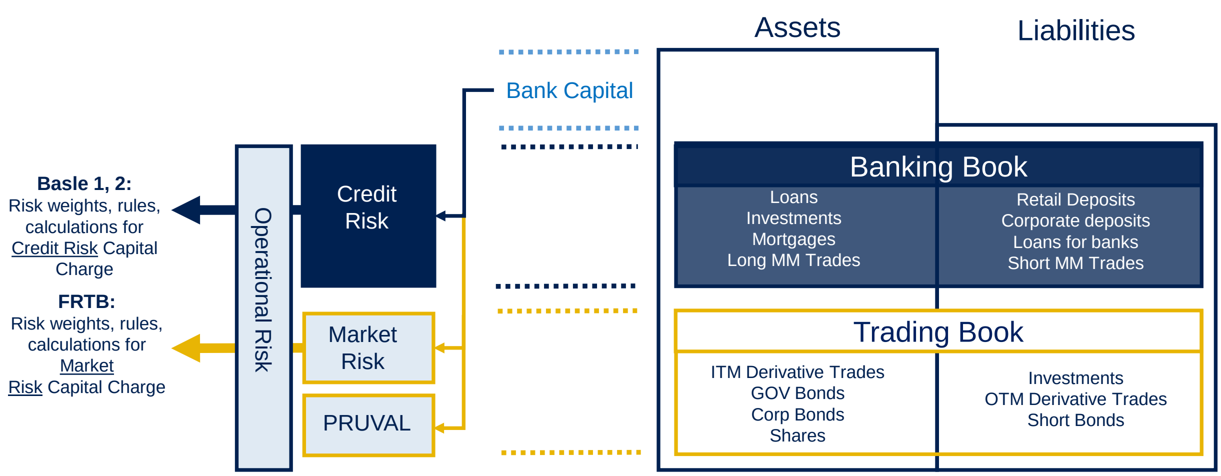


Note: A risk sensitivity is a calculation that approximates the P&L of a position or portfolio if a market data input is shifted by a standardized amount (e.g. 1 basis point).

A full revaluation approach does not require risk sensitivities to be produced. It instead takes market data (or risk factor) inputs, applies them to the trades and positions within the portfolio and revalues the entire portfolio using the bank’s quantitative models. Multiple revaluations are required for attribution of P&L to individual risk factors. Full revaluation is a more accurate approach than the risk sensitivity approach. But it is also computationally more expensive, requiring more powerful IT systems to perform the calculations.

4. Market Risk

Banks need to have sufficient capital set aside to protect against adverse movements in market prices. This is often referred to as market risk capital. FRTB will define the requirements for this. These requirements include risk weights, aggregation rules, definition of risk factors and other inputs as well as the formulae used in the various calculations.



FRTB stands for “Fundamental Review of the Trading Book” which is a term used for the standard published by the Bank for International Settlements (BIS) Basel Committee on Banking Supervision, called “Minimum Capital Requirement For Market Risk”, January 2019. The

The standard covered the following areas:

- The Trading Book and Banking Book Boundary
- The treatment of credit in market risk calculations
- Calibration to stressed market conditions
- Movement of VaR to Expected Shortfall
- The comprehensive incorporation of the risks of market illiquidity
- The treatment of hedging and diversification
- The relationship of internal models with standardized approaches
- A revised Internal Models Approach
- A revised Standardized Approach

While all of these areas are important for banks that are subject to FRTB regulation, the primary question that most banks are interested in answering is:

Should they use the internal models approach (IMA) or should they use the standardized approach (SA)?

The answer to this depends on a number of factors:

- Whether the bank is willing to invest in an overall IT and process infrastructure that has the ability to support IMA calculations
- The cost-benefit trade-off for each trading desk of doing IMA (versus doing SA only)
- The ability of each trading desk to pass the tests required to allow it to do IMA
    - P&L Attribution test
    - VaR back-test

4.1. FRTB IMA

The regulatory capital charge for a bank under the FRTB IMA (Internal Models Approach) will be based on the “Expected shortfall” (ES) risk measure. The ES value is calculated daily for the in-scope positions. In scope positions are determined by checks which are applied at trading desk level. The ES measure is based on the 97.5th percentile confidence level. In calculating the ES, liquidity horizons are used to scale an ES value which assumes a base horizon of 10. Part of the ES calculation involves the inclusion of a period of stress in the observation period. The correlations between risk factors that experienced the stress also need to be calculated. ES calculations require the input of both current (recent) observations and historical observations. For recent observations, banks must update their market and risk data at least once a month. The bank also needs to perform frequent market reviews to determine whether market prices are subject to changes material enough to alter the ES result. Flexibility is key here and the solution will need to allow users their own period of observation. The Standard states that the FRTB-IMA approach should, for example, allow a bank to calculate its Expected Shortfall using a shorter observation period where this is justified by an increase in market volatility. In this case, however, the period should be no shorter than 6 months. For ES calculations that use stressed observations banks need to specify the 12-month period of stress where the portfolio experienced the largest loss. The period needs to go back to and include 2007.

The aggregated capital charge trading desks approved for IMA will either be the most recent calculation or a weighted average of the previous 60 days – whichever is the largest. The result is scaled by a multiplier which ranges from 1.5 to 2.0 depending on the results of the VaR back-tests.

There are three components under IMA

- An ES calculation for Modellable Risk Factors
- A separate stressed ES calculation for Non Modellable Risk Factors
- A Default Risk Charge

The diagram below illustrates the relationship between these three components:

IMA Capital → IMCC + NMRF + DRC

IMCC → Internal Models Capital Charge

- For Modellable Risk Factors only
- Based on ES – Expected Shortfall*
- … 97.5 percentile calculation
- Risk specific liquidity horizon over 10-120 days
- Limited diversification benefit**
- Capital multiplier 1.5

+

NMRF → Non Modellable Risk Factors

- Calculated at Risk Factor Level using ES
- Where RFs do not have enough RPOs***

+

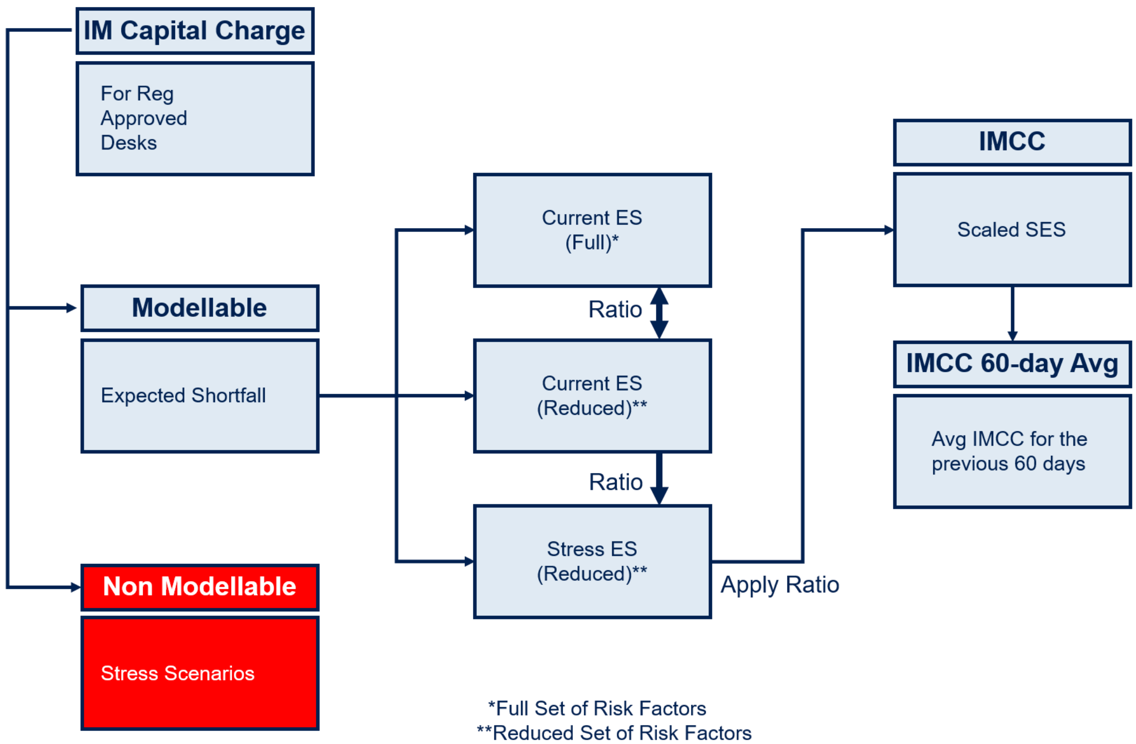
DRC → Default Risk Charge

- For credit and equity instruments
- One-year horizon at confidence level
- Liquidity horizon floored****
- Calibrate correlations over 1-year stress period
- Mandatory PD floor at 3 bp

*previously calculated using a VaR methodology
**average of fully diversified and constrained capital charge)
***RPOs = Real Price Observations. Trades or Committed Quotes
****at 3 months for equity and 12 months for debt instruments

The ES calculation must be calibrated to a period of stress.

- This calibration uses an “indirect” approach based on a reduced set of risk factors.
- Reduced set of risk factors must be modellable and must explain a minimum of 75% of the variation of the P&L in the ES model
- IMCC is then
  - the Stress ES
  - calculated reduced set of risk factors scaled by the ratio of the Current ES using the full set of risk factors to the Current ES using the reduced set of risk factors



4.2. IMA Eligibility

The IM Capital Charge (IMCC) is applicable for trading desks that have regulatory approval to use internal model for regulatory capital calculation. A trading desk needs to prove it is qualified to use the FRTB-IMA for calculating market risk capital. Broadly speaking, two sets of tests need to be passed in order for a trading desk to be allowed go with the IMA approach

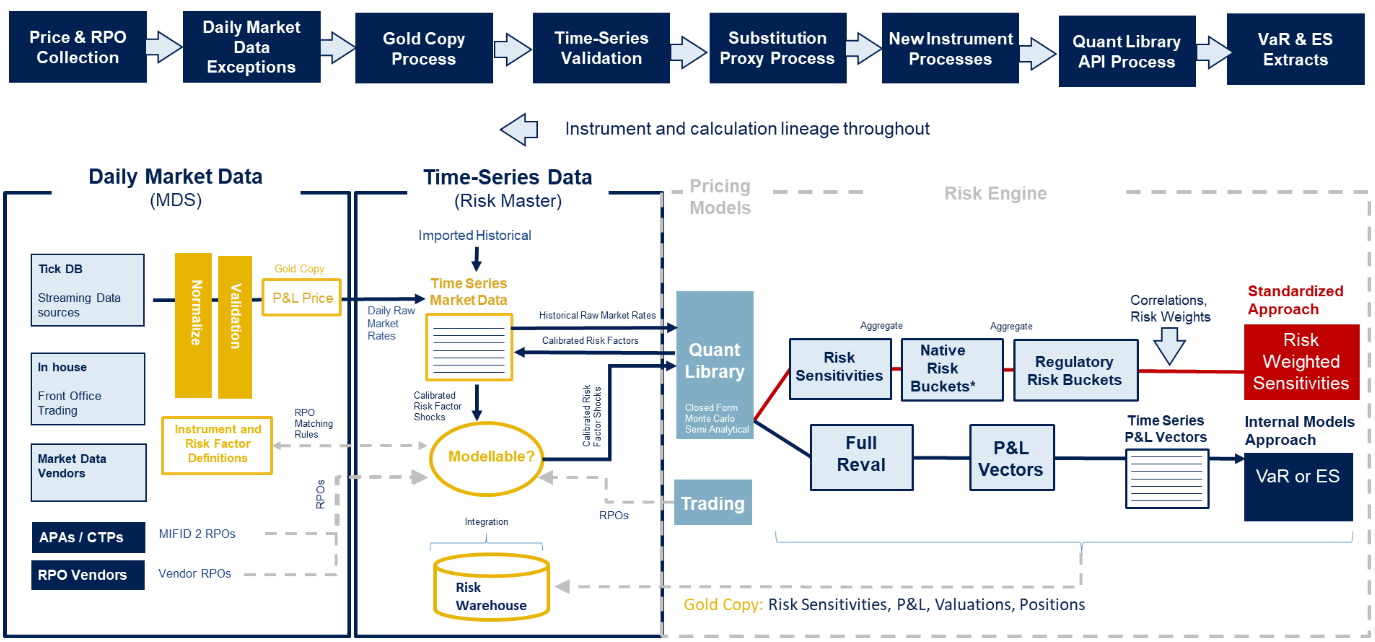
- bank-wide qualitative tests
- trading desk-level quantitative tests

4.2.1. Qualitative IMA Eligibility Tests

The qualitative tests requires that the regulator is satisfied that the bank has a robust risk management framework in place. This includes ensuring that there are a sufficient numbers of staff skilled in the use of pricing models across Front Office, Risk, Internal Audit and Finance. The regulator also needs to ensure that the bank has a proven track record of accuracy in measuring risk and that it conducts stress tests at frequencies sufficient to allow for the incorporation of market-disruptive events that might impact the parameters of FRTB calculations. The bank needs to ensure that the positions being held in the trading book that are being used for regulatory capital calculation purposes have passed the required trading-book eligibility tests. The frequency of back-testing and P&L attribution and confirmation that pricing models are being validated by a team that is independent from the trading desk are also key qualitative checks.

Banks are permitted to use different models to calculate regulatory capital charges than those they use in the operation of their daily risk management tasks. As long as the pricing models that are embedded in both approaches are similar, and can be verified to produce similar results, the regulator will permit a separate calculation process for regulatory capital. The regulatory capital model needs to be based on the same methodologies as the operational model in terms not only of risk factor identification but also in relation to calibration tools and use of proxy pricing. This will require both automated proxy pricing and model parameter calibration.

For a bank to be allowed to calculate capital using FRTB-IMA, it is mandatory that it has a robust set of Pricing Model Validation processes in place. A compliant FRTB ecosystem will be able to record definitions, inputs, outputs and approval statuses of "Pricing Models". The diagram below provides and overview of (left-to-right) data flow



A few observations from a data perspective:

- Daily Market Data: process for centralizing and validating market data that is used for valuations purposes

- The bank's Quant Library is used to:
    - calibrate model parameters
    - calculate the trade and position $valuations
    - calculate risk sensitivities

- The Standardized Approach does not require market data (neither daily or historical) and is therefore outside of the scope of this document
- The Standardized Approach requires today's market risk positions (i.e. risk sensitivities) as well as a set of risk weights and correlations prescribed by the regulator
- The Internal Models Approach requires a trading desk to calculate market risk capital using a Value-At-Risk (VaR) or Expected Shortfall (ES) methodology
- The calculations for both VaR and ES are based on historical P&Ls calculated using historical time-series of market prices and rates.

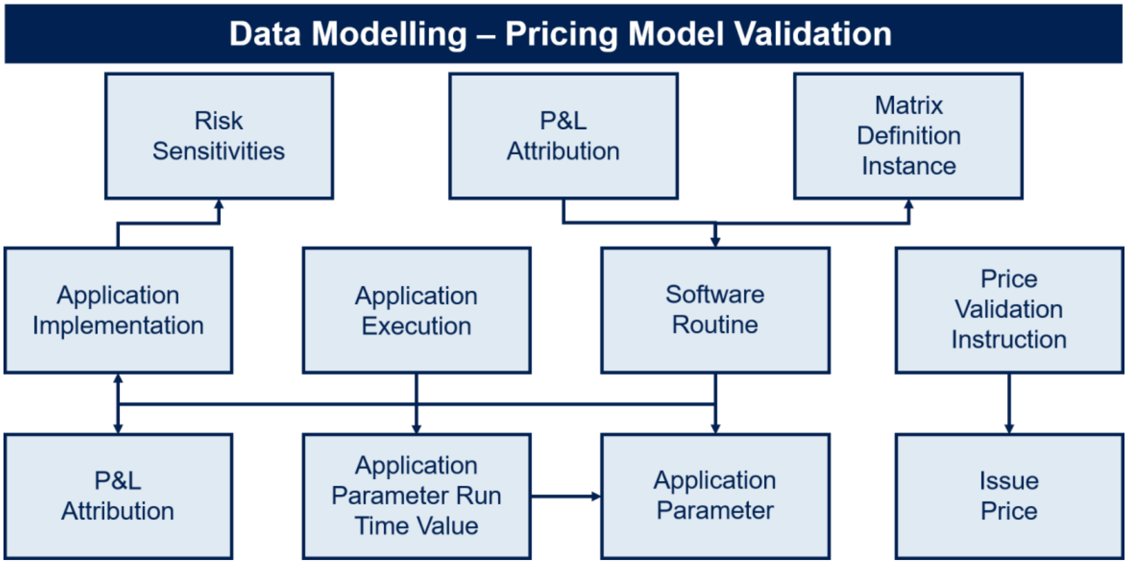
A common and well known example of a pricing model is "Black-Scholes" – which is an industry standard closed-form solution for valuing European call and put options. Other examples of models, techniques and calculations that are used in the pricing of derivatives and other instruments are SABR, Black's Model, Monte Carlo and Base Correlation. They are all used to calculate the prices/values of positions in securities or derivatives. Models can be thought of as the implementations of the mathematics required to calculate fair value valuations. Most models are fair value or pricing models. A simple example of a pricing model is V=P*Q. Where V= the valuation of the security, P is the price of the security and Q = the amount of the security the bank is holding. When calculating the V for derivatives, e.g. call options, however, you need to take account of the fact that the option will only have a value if the P (P in this case would be the Price of the underlying Security) is greater than the strike. So you need to know the probability of P being greater than the strike at maturity – so the model becomes more complicated requiring interest curves and probabilities as inputs. Probabilities of the underlying prices are derived using market volatilities of those prices. More complex models involve the calibration of model parameters for use in simulating (e.g. using a Monte Carlo simulation) the projected values of derivatives as time moves forward. SABR, Heston and Hull-White 2-Factor are examples of models that require this two-step process:

- Calibrate model parameters
- Use the calibrated parameters to simulate price-paths for path-dependent derivatives such American Options and options and options with features such as barriers.

The data modelling for Pricing Model Validation needs to be able to capture

- the Library that model or routine belongs to
- the name and version of the model or routine
- the list of market data inputs to the model
- the list of parameter inputs to the model
- the last calibration date of the parameter inputs
- the Model approver
- the Last Validation date of the model

The diagram below gives an overview of the type of data entities that are required for the management and validation of Pricing Models.



4.2.2. Quantitative IMA Eligibility Tests

The primary quantitative tests for IMA-eligibility for a trading desk are

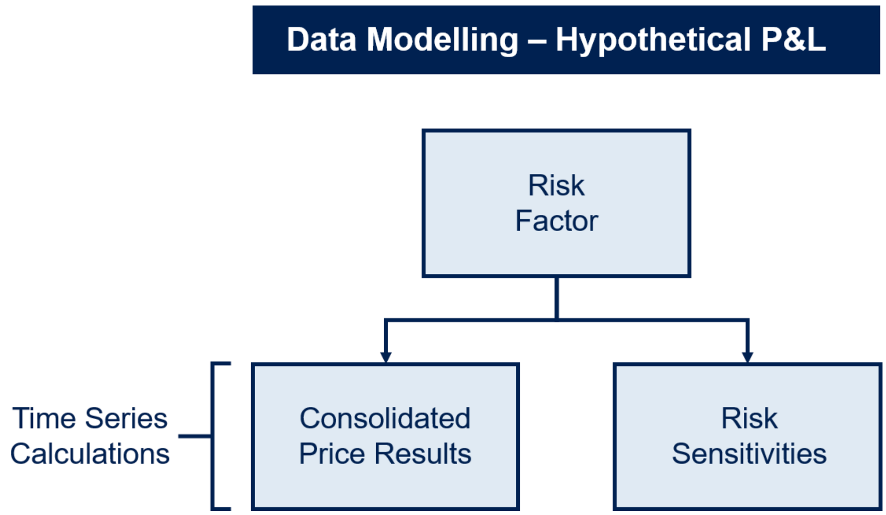
- the VaR back-test
- the P&L Attribution test

The VaR back-test was part of most bank's market risk controls prior to FRTB but under FRTB it will become more rigorously enforced. The P&L Attribution test is new to FRTB. If a trading desk fails to pass either of these quantitative tests, it will need to revert to the Standardized Approach.

4.2.2.1. The VaR Back-Test

VaR back-testing is to be carried out against 97.5% and 99% VaR on a 1-day horizon, and will need to be performed against the trading desk's hypothetical P&L. The Standard defines hypothetical P&L (HPL) as the gains or losses that would have arisen from holding position quantities constant and just applying market data moves to them over the period in question. If a risk sensitivity approach was used here then from a data perspective, and in the context of the Curve Shift methodology described above, this would involve

- mapping market data points to risk sensitivity points
- "shifting curves" by daily moves in market data
- applying the daily "curve shifts" to risk sensitivity positions



The time-series curve shifts applied to the starting risk positions will result in a distribution of hypothetical daily P&L values by risk factor. 1-day 99% and 97.5% confidence intervals (CIs) can be determined using the distribution. An outlier occurs whenever a historical daily hypothetical P&L is greater than the VaR at 99% CI. In a year with 260 trading days, at the 99% CI the bank would expect to have no more than 3 back-testing breaks (rounded up from 2.6). If there are greater than 3, the risk management model will be deemed suspect under the Standard and will require investigation and potential remediation.

It should be noted that this is a test of the VaR model and not a test of a VaR limit. It is a test of the VaR model that will be used to calculate a VaR risk measure. In fact, indirectly, the approach tests both the VaR model and the Front Office Pricing Models simultaneously. This is because

- any risk sensitivities used in the calculation will have been created using the bank's Front Office pricing models
- there is no 'noise' from position amendments, fees, commissions etc., and, finally
- the VaR CI is calculated using clean historical P&L values create by Front Office Pricing model.

If the VaR model is accurate the number back-testing breaches should be very close to the number that the model predicts

As mentioned above, a compliant FRTB ecosystem will need the ability to both
- store all the time-series data required for the FRTB-IMA VaR calculations and
- to integrate with a model-validated Pricing Library to support a parameterized approach to these calculations.

So, should a trading desk use risk sensitivities for its VaR back-test or should it use a full revaluation approach? The Standard, in fact, is not prescriptive on this question. P&Ls used for the VaR back-test are calculated across all risk factors that the trading desk is exposed to irrespective of whether a full revaluation approach or a risk-sensitivity approach is used. If the bank uses a risk sensitivity approach then, for example, a 10-day P&L will be generated for each risk sensitivity that the desk is exposed to and the resulting P&Ls will be aggregated into a desk level P&L. If, on the other hand, the bank uses full a revaluation approach for VaR then the full revaluation model will take as input the market data for each risk factor in the model and use this market data to generate fair values for the desk's trades/positions. The difference between this value and the value generated from the market data from 10 days ago will be the full revaluation P&L.

4.2.2.2. The P&L Attribution Test

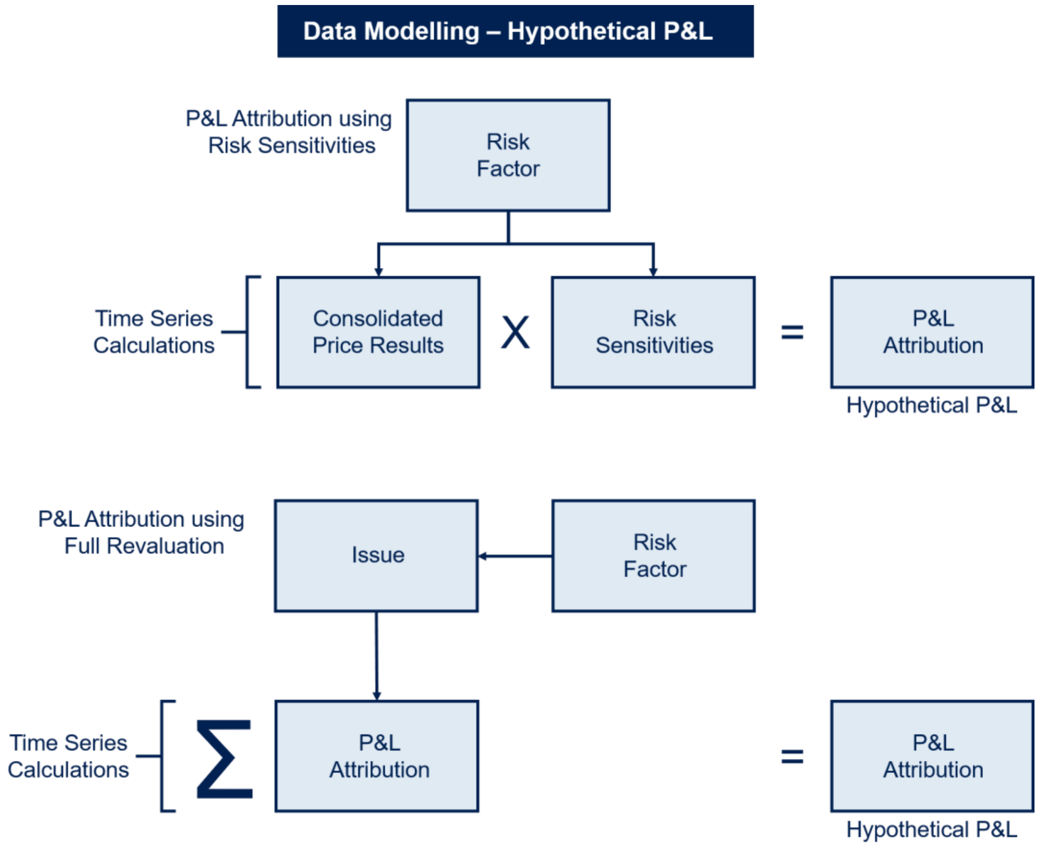
FRTB is driving an alignment of models and data between Risk and Finance

While back-testing has always been a requirement, as mentioned, the need to pass a *P&L Attribution* (PLA) test is new. It revolves around the concepts of Risk-Theoretical P&L (RTPL) and Hypothetical P&L (HPL). Like the VaR back-test, it is a test that is applied at trading-book level. RTPL is P&L calculated in Market risk models. HPL is the Front Office or Official P&L over the same period assuming that positions are held constant and market moves are applied to them. From a regulatory perspective, the aim of the PLA test is to test that Risk models used for capital calculations are closely aligned to Front Office models (i.e. models used for Official Valuations which are in turn used in Product Control for Daily P&L purposes). There are three broad drivers that can cause divergence between the results of Risk and Finance models:

1. The definition of the risk factors that determine the market data inputs
2. The market data itself
3. The valuation methodology, i.e. full revaluation vs risk factor sensitivity based approximation.

As mentioned, with regard to the valuation methodology, FRTB does not prescribe that risk models use full revaluation but, one of the arguments being made by industry practitioners at the moment, is that if the risk models do not use full revaluation the PLA test will likely fail. The approximations inherence in a risk sensitivity approach will cause the test to fail.

The data modelling diagram below provides a high level overview of the data entities required under both a full revaluation and a risk sensitivity approach.



The PLA test requires that an Unexplained P&L value needs to be calculated each day where

Unexplained P&L = RTPL less HPL

It is based on two test metrics

- the Spearman correlation metric to assess the correlation between RTPL and HPL
- the Kolmogorov-Smirnov (KS) test metric to assess similarity of the distributions of RTPL and HPL

Using the thresholds below the outcomes of these test metrics will determine whether a trading desk falls into the Green Zone or the Red zone. If a trading desk is not in either the Green or the Red zone then it will be deemed to be in the Amber zone.

PLA Test Thresholds and IMA Eligibility

Zone	**Spearman Correlation**	**Kolmogorov-Smirnov**	**Trading Desk IMA Eligibility**
Green	0.8	0.09 (p-value=0.264)	Eligible for IMA
Red	0.7	0.12 (p-value=0.055)	Not eligible for IMA => Use SA
Amber			Subject to a Capital Surcharge

4.3. The RFET, the treatment of NMRFs and IPV

Under the FRTB Internal Models Approach (IMA), only those risk factors which are considered modellable will be eligible to be included in a trading desk's FRTB-IMA calculations. The test that checks for a risk factor's Modellability status is called the Risk Factor Eligibility Test (RFET). For a risk factor to be deemed modellable, there must be "continuously available *real* prices for a sufficient set of representative transactions". These continuously available real prices are called Real Price Observations (RPOs). A price will be considered real if it is based on either a traded price or on a "committed" quote.

The treatment of RPOs and Non Modellable Risk Factors (NMRF) is multi-faceted. It involves

- Identification of RPOs using the bank's own traded prices and quotes
- identification of RPOs using the externally traded or quoted data
- the mapping of RPOs to risk factors
- identification of the stressed period that the risk factors are being calibrated to for the purpose of real price identification

When in-house traded or quoted RPOs are mapped to risk factors an interesting benefit for the business/trading desk will be that the risk factor can potentially be considered to be independently price-tested (i.e. IPV'd). More on this below.

4.3.1. Vendor versus In-House Solutions to the RFET

Market data vendors are working hard to come with solutions for identifying real prices and aggregating real price data. When these solutions are finalized it will be interesting to see the shape that they take and the consistency of approach across vendors. Some of the open questions are

- Will consensus price vendors amend existing price submission processes to allow banks to submit real price flags?
- How will vendors aggregate real price data? Will they try to determine, effectively guess at, the shape of a typical bank's risk factor given that they will have no transparency on the risk positions a bank runs? Or will their solutions allow banks to customize risk factors via dedicated user interfaces?
- Will individual vendors have different ratios of traded price data to committed quotes? Will some vendors specialize in quotes whereas others will only have access to trades?
- Will vendors calculate Risk Factor modellability themselves? Or will they just send real prices to banks? If the former then how will they determine what a Risk Factor should look like for a bank given that they have no transparency on a bank's risk positions?
- Will banks in a particular region club together to collate real price data common to them?
- If vendors do support determination of Risk Factor modellability, what kind of approximations will they support? Will, for example, all interest rate swaps with a maturity of approximately 1 year be included in their 1 year maturity real price determination? Is the underlying tenor of the swaps (e.g. 3m vs 6m) relevant? While aggregating data into maturity buckets, what kind of interpolation logic will be applied?

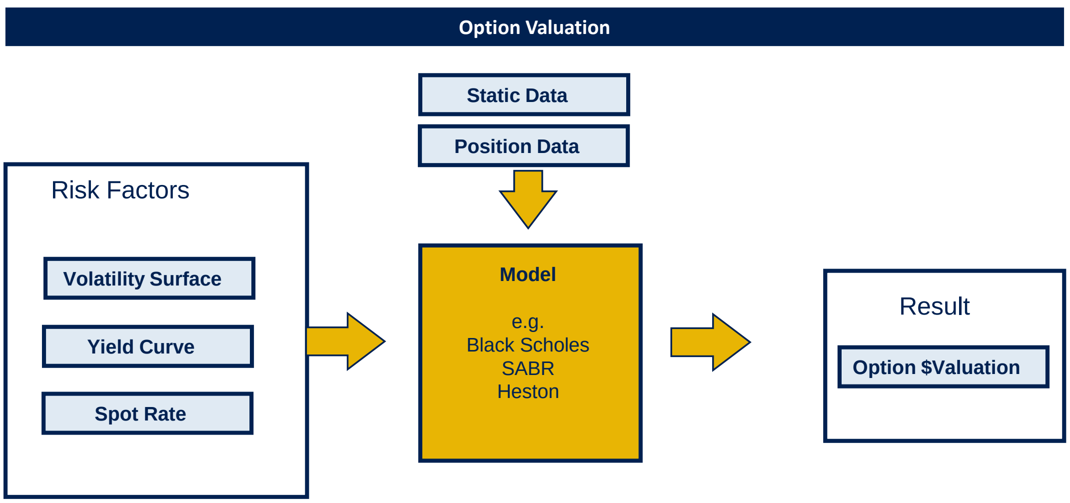
4.3.2. Mapping of RPOs to Risk Factors

Whatever approach is taken to consuming RPOs, whether they are sourced externally via vendors or whether they are internal trades or quotes, one aspect of a bank's approach that will need to be considered is the mapping of RPOs to the bank's risk factors. A rule-based approach will be required.

Take an OTC option trade (RPO). It can be said to have three risk factors:

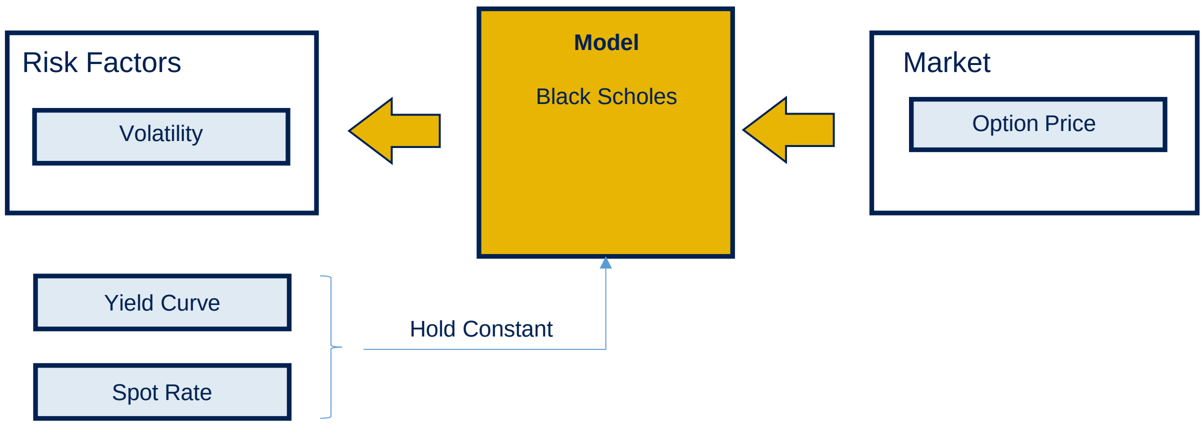
- A spot rate
- A yield curve
- A volatility surface

In the example in the screen shot below, a pricing model takes these risk factors as inputs and generates a valuation for the option based on the size of the position or trade.



As the diagram below shows, the process can be reversed and a risk factor (e.g. the volatility surface) can be backed out of the prices of traded or quoted options. Volatilities backed out of option prices in this manner are called implied volatilities.

Backing Volatility out of Option Prices



If RPOs are loaded into a trade or quote repository rules are required which will map these RPOs to the risk factors. The two dimensions upon which RPOs are typically mapped to their risk factors are:

- Time-to-maturity
- Delta

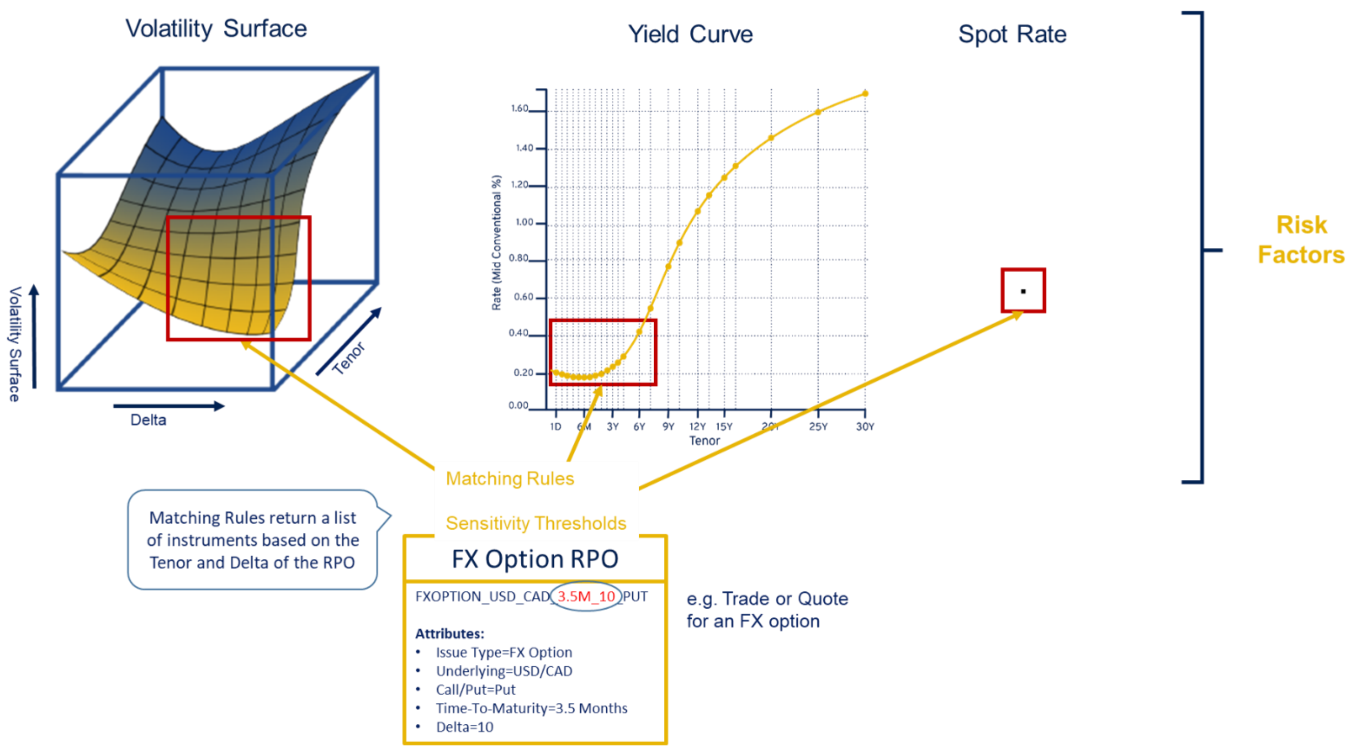
Time-to-Maturity: this is the remaining time-to-expiry of a swap, forward or option trade or quote. If an RPO has a short remaining time-to-maturity then the RPO matching rules will map to rates or volatilities that sit along the short end of a curve or volatility surface.

Delta: this is a measure of the moneyness of the option, e.g. a delta of 50 means a call option is at-the-money. A delta of 95 means the call option is deep in-the-money. A delta of 10 means the call option is out of the money. The delta of the RPO will be used to choose which are of the volatility surface volatilities can be matched to for the purposes of determining RPO counts (and therefore Modellability checks) for that surface.

Pre-requisites for an RPO matching rule solution include:

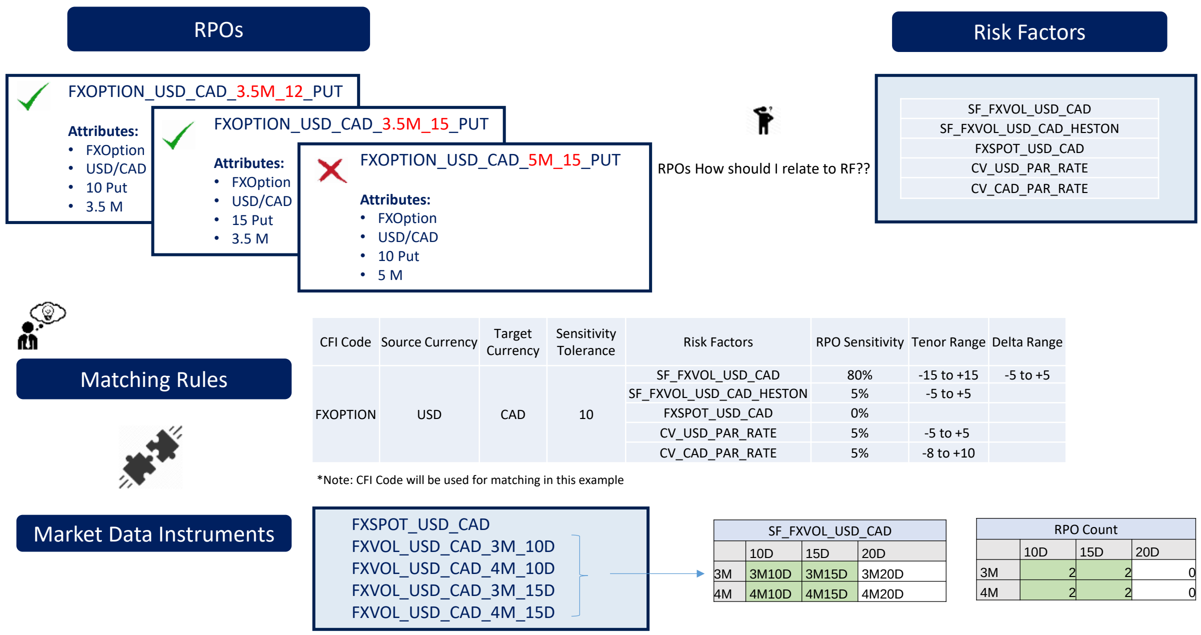
- The ability to standardize RPO instruments
- The ability to standardize instruments that belong to curves and surfaces (market data instruments)
- Functionality which can flag to users that a risk factor is about to become non-modellable
- The ability to calculate risk factor modellability based on RPO counts

An illustration of an RPO matching rule approach where the RPOs are FX Options and the Risk Factors are the Volatility Surface, the Yield Curve and the FX Spot Rate:



And the examples in the screenshots below show how multiple FX Options (acting as RPOs) are matched to their respective risk factors:

- The USDCAD spot rate
- The USDCAD Volatility Surface
- The USD yield curve



CFI Code	Source Currency	Target Currency	Sensitivity Tolerance	Risk Factors	RPO Sensitivity	Tenor Range	Delta Range
FXOPTION	USD	CAD	10	SF_FXVOL_USD_CAD	80%	-15 to +15	-5 to +5
				SF_FXVOL_USD_CAD_HESTON	5%	-5 to +5	
				FXSPOT_USD_CAD	0%		
				CV_USD_PAR_RATE	5%	-5 to +5	
				CV_CAD_PAR_RATE	5%	-8 to +10	

*Note: CFI Code will be used for matching in this example

SF_FXVOL_USD_CAD	10D	15D	20D
3M	3M10D	3M15D	3M20D
4M	4M10D	4M15D	4M20D

RPO Count	10D	15D	20D
3M	2	2	0
4M	2	2	0

4.3.3. Criteria for real price determination

An executed trade is clear evidence of a real price. There isn’t really a lot of room for interpretation there. The size of the trade and the potential for collusion between trade counterparties to create a trade that will support a regulatory capital target are two potential exceptions to this. But there are not many. With committed quotes, however, things are less clear. Some or all of the criteria below should be taken into account to identify committed (executable) quotes:

- Both “bid size” and “ask size” need to be available from the contributor to be deemed executable
- Exchange prices (futures, options, equities) are typically executable quotes
- Bond prices from bond trading platforms are typically executable quotes
- Prices from SEFs (swap execution facilities) are typically executable quotes
- Composite prices are not executable
- Evaluated prices are not executable
- A mid-price on its own (from any source) is not executable
- A model price can only be considered executable if
  - all of the inputs to the model are real
  - bid and ask prices can be backed out from the model

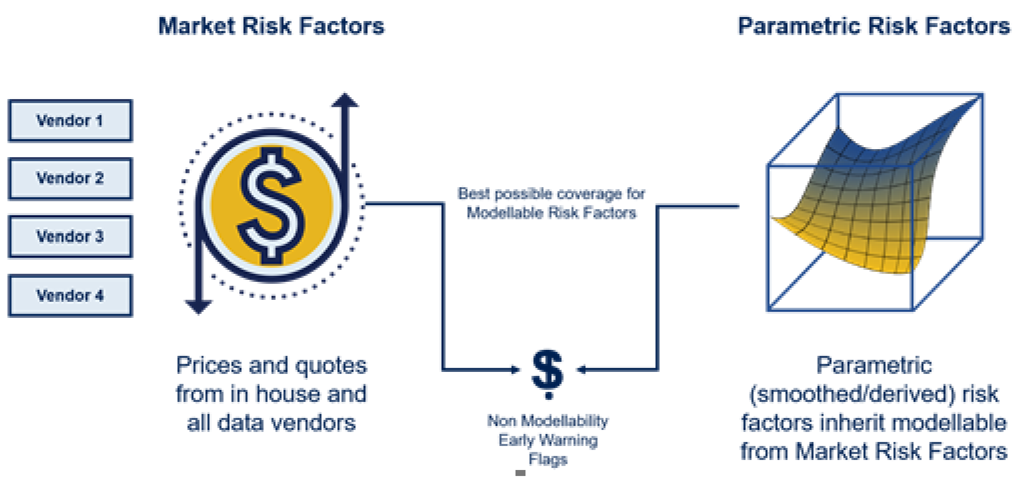
4.3.4. FRTB RFET Overlap with IPV & Regulation

The concept of a committed quote in FRTB NMRF analysis overlaps with concepts from other regulatory and financial reporting standards. For example,

- An FRTB committed quote has similar characteristics to an executable price (where an executable price attracts a zero AVA) in CRD4 Prudential Valuation (PRUVAL) standards
- Level 1 positions in the IFRS fair value hierarchy can be deemed to have similar liquidity characteristics to those of both FRTB committed quotes and PRUVAL executable quotes
- As discussed, if an internally-traded RPO or an internal RPO quote can be mapped successfully to a bank's risk factor then that risk factor can be deemed to be "on-market" for IPV purposes. i.e. the bank would not have traded or made quote if the trade (and therefore its risk factor levels) was off-market

4.3.5. Market versus Parametric Risk Factors

The Modellability of risk factors can only be determined for "Market" risk factors below. Modellability cannot be determined for "Parametric" risk factors. Solutions are therefore required which can associate "Market" risk factors with "Parametric" risk factors



Valuations and market risk calculations are usually calculated using parametric risk factors. The ability to trace calculations from:

Valuation Record -> Parametric Risk Factor -> Market Risk Factor

will be required in all FRTB solutions for audit and data lineage purposes.

5. Liquidity concepts in valuations and market risk

Market liquidity is a market's ability to purchase or sell an asset without causing a material change in the price of the asset. It describes the asset's ability to sell quickly without having to reduce its price. Liquidity is about how big the trade-off is between the speed of the sale and the price it can be sold for. In a liquid market, the trade-off is mild: selling quickly will not reduce the price much. In a relatively illiquid market, selling it quickly will require cutting its price by some amount.

The determination of the liquidity of the markets that underlie market data sources is key function that IPV and Valuations teams perform. Functions such as:

- Fair Value Hierarchy and IFRS13
- Prudential Valuations
- Bid-Ask Reserves and
- Day 1 P&L

require processes that review and determine the liquidity of the underlying market data.

In Market Risk, the liquidity of financial instruments is catered for by a different set of controls, these include:

- The liquidity horizon in the FRTB expected shortfall calculation
- The risk factor modellability tests

Both of these market risk measures/controls are designed to cater for the fact that the liquidity of the instruments in a bank’s trading book typically vary widely for different across risk classes and instrument types.

5.1. Market liquidity

Markets in their purest form are relatively simple constructs. There are buyers, sellers, ask prices, bid prices and a mid-price. There isn’t much more to them than that. Buyers always have to buy at the price the seller is willing to sell at (the ask price). And sellers always have to sell at the price the buyer is willing to buy at (the bid price). These basic concepts apply to anything that is being bought and sold in any market in the world. Financial markets are like any other market. Exactly the same principles apply as apply for the exchange of goods and services in the rest of the economy. The perceived complexity comes from the fact that in financial markets the products that are being sold are less familiar to people. Exchanging money for widgets in a manufacturing environment is a relatively straight-forward concept. Indeed, exchanging money for a bond or an equity is also a relatively straight-forward concept. But conceptualizing payment for an OTC derivative that transfers interest rate risk from a fund to an investment bank is more difficult. Or when a pension fund manager transfers 50 year inflation rate risk to an investment bank via an inflation swap, the concepts become that bit harder to grasp. They become harder again to grasp when non-market practitioners realize that the inflation swap is exposed not just to inflation rate risk but also to interest rate risk because the future cash flows generated by the inflation swap need to be discounted with an interest rate curve. Explaining that the interest rate curve that is used to discount the future cash flows of the swap depends on the collateral posted against the swap, can lead to further confusion[2]. And telling someone who doesn't have experience with derivatives that the asset manager who needs to post collateral has an option to post dollars, sterling or US Treasuries as the collateral amounts, will likely lead to that final bit of confusion. And if it doesn't it certainly will when you tell him that the optionality he holds when posting cash or bonds to collateralize to the swap position means he has exposure to volatility rates that need to be derived from the market.

Luckily, none of these concepts need worry the market data practitioner. It helps if he understands them but he doesn't need to. All he needs to know is the fundamentals of how a market works, i.e. there are buyers, sellers, ask prices, bid prices and a mid-price. These concepts are illustrated using the diagram below.

5.2. Liquid versus Illiquid Markets

Markets can be liquid or illiquid. If they are liquid, there is lots of trading going on and their bid-offer[3] continuums as illustrated in the diagrams below are crowded, leading to a small gap between the highest bid and the lowest offer. This gap, whether big or small, is called the bid-offer spread. As you can also see from the diagram below, in an illiquid market the bid-offer continuum is typically sparsely populated, leading to a wide bid-offer spread. In illiquid markets, sellers find it hard to sell and buyers find it hard to buy. When bid-offer spreads are wide enough, mid-price valuations become meaningless and large reserves for bid-offer spreads need to be taken on to the firm's balance sheet.

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[2] A swap that is fully collateralized with margin cash posted on a daily basis should be discounted at the rate of return that the cash would give an investor if he invested it for one day (the overnight rate)

[3] The terms "offer" and "ask" are analogous in the context of financial markets

5.3. Liquidity Indicators

There are different ways to measure liquidity. The size of the bid-offer spread, the number of trades or quotes in a given time-period, the length of time it takes to exit a position without moving its price. The table below provides an overview of the different types of liquidity indicators there are and the regulations that they apply to

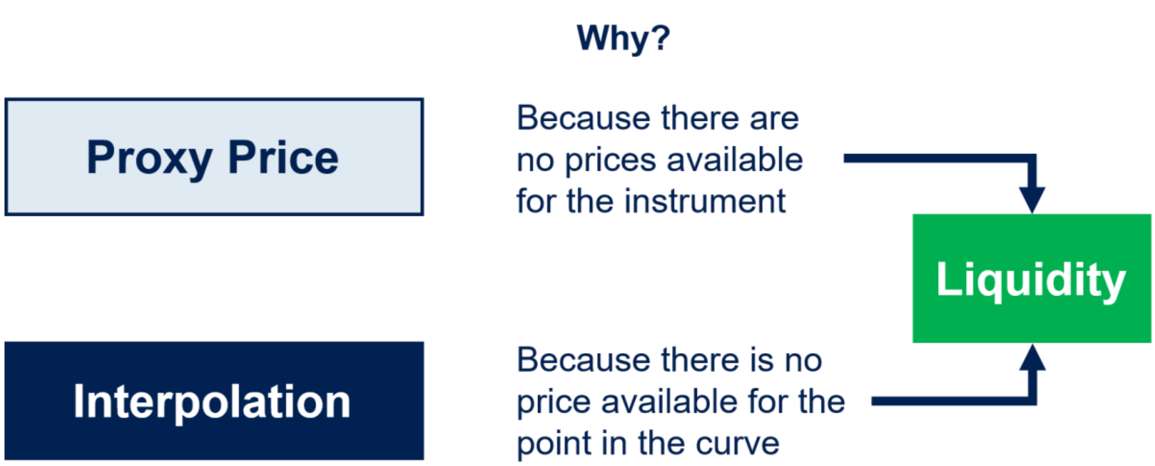
Liquidity Indicator available in data	Related Regulatory Concept
Size of Bid-Offer Spread	N-PORT Bid-Offer Provisioning PRUVAL Close-out Costs AVA
Number of ticks in a time period	N-PORT Liquidity Classification IFRS13 Level 1/2/3 Classifications
Market Depth Distribution of price sources	PRUVAL Market Price Uncertainty AVA N-PORT Liquidity Classification
No of trades in a time period	N-PORT Liquidity Classification IFRS13 Level 1/2/3 Classifications
Exit Time for a position	PRUVAL Concentration AVA FRTB ES Liquidity Horizon
Liquidity breakdown of fair value balance sheet	N-PORT Liquidity Classification IFRS13 Level 1/2/3 Classifications

The table below apply describes some of the approaches that can be used with GoldenSource's Market Data Solution (MDS) to derive liquidity indicators.

Liquidity Indicator	Related Regulatory Concept	MDS Functionality
Size of Bid-Offer Spread	Bid-Offer Provisioning PRUVAL Close-out Costs AVA	Price Types in MDS allow bid and ask curves to be created. Risk Sensitivities can be used to calculate required reserve amounts
Number of ticks in a time period		Tick Filtration solution allows snap times to be defined and tick counts per instrument to be calculated
Market Depth Distribution of price sources	PRUVAL Market Price Uncertainty AVA	The standard deviations of the distribution of contributor prices allows a 90% CL MPU AVA to be calculated
No of trades in a time period		(Backward looking view of liquidity). Trade counted by instrument in a given period
Exit Time for a position	PRUVAL Concentration AVA FRTB ES Liquidity Horizon	Bid-offer spreads can be widened if the number of days to exit a position exceeds 10 RiskHub time series of market moves using pre-defined Liquidity Horizons allows market risk capital to be calculated using Expected Shortfall calculations
Asset Class Taxonomy	IFRS13 Level 1/2/3 Fair Value Balance Sheet	Use Issue Types to determine Level 1/2/3 Classification

5.4. Proxy Pricing for Illiquid Instruments

Proxy pricing, model pricing and interpolation are methods for deriving prices when there are insufficient bids and asks available in the market to come up with a price that can be used for valuation purposes.



When securities or curve points are illiquid, there are a lot of different ways that proxy / model prices can be derived for them. The use cases described below cover proxy pricing, interpolation and calibration. But they are all doing the same thing; deriving prices where there is insufficient liquidity in the market to get them from contributors. Using combinations of native market data derivation functionality and APIs to 3rd party libraries, a market data system needs to ensure that there is a framework in place that can handle each of these use cases.

Securities

- Use one security price as a straight proxy for the illiquid security[4]
- Use % change in a security price as a proxy for the % change in price for the illiquid security
- Use % change in a benchmark index as a proxy for the % change in price for the illiquid security
- Use yield on a bond with similar credit rating, sector and maturity to derive (e.g. using a Quantlib function) the price of the illiquid bond

Interest Rate Curves

- Proxy curve = Fixed spread over an existing curve
- Proxy curve (e.g. 6m Libor) = Tenor basis spreads (e.g. 3s6s) added to a base curve (3m Libor)
- Proxy curve (e.g. CHF Libor) = Cross currency basis spreads (e.g. USDCHF xccy basis swaps) added to USD Libor curve to derive a CHF Libor curve
- Proxy curve points where missing curve points are derived using linear interpolation / extrapolation
- Proxy curve points where missing curve points are calculated using a whole curve spline / smoothing (e.g. Cubic spline) interpolation routine

5.5. Impact of illiquid prices on historical time-Series

Where there are illiquid instruments, it is very likely that the historical time-series of prices for those instruments will contain gaps, stale prices and other anomalies. This creates the need to have tools that will check for the quality of the time-series data as well as correct it. Typically time Series data (historical prices and rates) can be validated in two modes:

- Automated mode
- Interactive Mode

Automated mode allows for the time-series data to be validated and checked every day.

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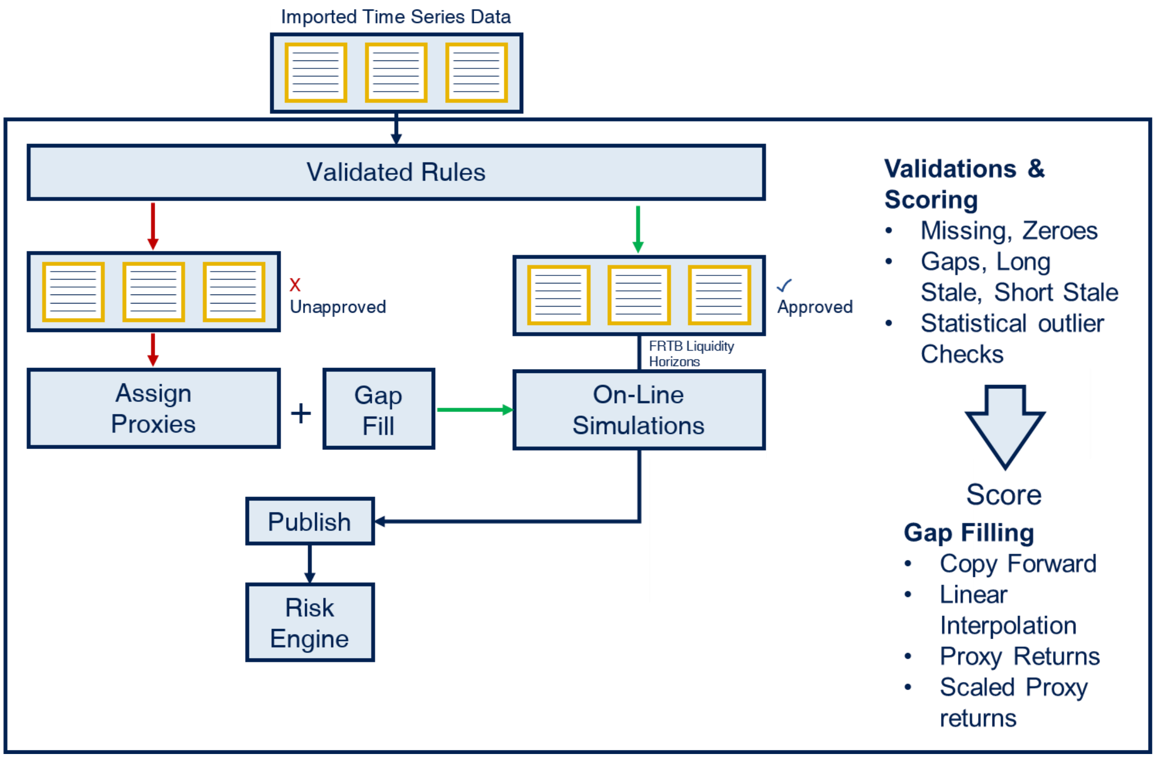
[4] The "illiquid" security or curve is the security or curve that the market data solution needs to calculate a proxy price / rate for

Validations – Automated Mode



Whereas running validations in interactive mode assumes that validations are run once (or possibly periodically on an ad-hoc basis) on the historical data using an interactive UI and do not need to be run again after that. Only recently added data needs to be validated after and this can be validated via the (potentially separate) daily market data validation process.

Valuations Analytics Mode

Validations Simulations
- Missing, Zeroes, Gaps
- Z-test
- Statistical Outlier Checks
- Gap Filling

Daily returns
Shocked returns

Standard Deviation
EWMA Volatility
Risk Factor views of results

In both cases (automated and interactive) the types of validation that are run are typically the same but when validations are run in automated mode specific data sets can be targeted for validation on a pre-determined schedule, e.g. stress period data sets, or periodically to capture statistical outliers, etc.

Typical checks that are required in a time-series validation process:

Basic Checks:

- Zeroes
- Nulls
- Long Stale - the max no. of days a price is unchanged before it is considered stale
- Short Stale - several short stale days within a long period

Statistical Checks:

- Outliers - distance from mean in terms of standard deviation
- Rolling Z-Score - rolling distance from mean in terms of standard deviation
- Auto-Correlation - how correlated is recent data with prior data?
- EWMA Correlation - same as above but more weight given to recent data

If the time-series validations identify errors or gaps in the series, then these errors need to be corrected. Typical gap filling approaches include:

- Copy forward from prior-day
- Linear interpolation
- Gap filling using the returns (price movements) of related (proxied) time-series