Regulation, Capital, and Margin: Quant Angle - I

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Related Topics: "XVA", Capital Management, Collateral,..

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I: Overview of Regulation & Capital Basics

Regulation and Quant/Strats - (1)

- Many changes – and much work – in the quant world are regulation-based: regulatory compliance and reporting, regulatory examinations, regulatory "optimization" (margins, collateral, CSAs, capital hedges, funding,...), model validation requirements, monitoring, CCAR, ...
- Fortunately, for quants/strats, much new regulation is complex and, for larger banks at least, requires profound amounts of new analytics development, documentation, and deployment.
- While not revenue generating per se, these activities are very visible at the top of the house, as capital numbers may be in the $100BN's, versus exotics trading book revenues in the $10MM's.
- Fees, charges, excess capital levels, lawsuits, failing stress tests,... are big concerns these days – and avoidance of them involve (shadow) revenues much larger than what quants typically work on.

Regulation and Quant/Strats - (2)

- At BofA, regulatory compliance currently is a very significant part of the work that the quant/strat group, and not likely to diminish.
- We have launched significant learning programs to "reschool" quants and to teach them capital basics.
- Quants (including myself) are not meant to be regulatory experts (legal and capital groups have this responsibility), so the quant focus is necessarily selective and targeted to those areas that involve analytics.
- My "tour" of regulation is therefore highly biased in its coverage (and my knowledge somewhat limited...)
- Fortunately, Prof. Abbott has covered much of the – important – history and institutional background, so we don't need to spend much time on that. We will focus on models and calculations.

Basel Reg Capital (and Margin)

- Basel Committee on Banking Supervision (BCBS) is a Basel-based committee tasked with developing international policy guidelines for banking supervision, especially around capital adequacy
- Founded by the Central Banks of the G10 countries in 1974. Current members include most developed nations, such as Sweden. Denmark not on the membership list!?
- Role is to formulate broad principles, issued in documents available on their web-site. It is up to the individual nations' Central Banks (and/or other bodies, such as the FDIC and OCC in the US) to turn recommendations into concrete regulation and supervision.
- Currently, banks have to simultaneously (!) worry about 5 different capital adequacy accords: Basel 1, Basel 2, Basel 2.5, Basel 3, Basel 4 (FRTB).

Dodd-Frank

- The Dodd-Frank Act (which leans on Basel 3) was signed into law in the US in July 2010. Based on a G20 agreement that means to stabilize the financial system through a variety of measures (clearing, transparency,..)
- The part that is most relevant for Wall Street is Title VII ("Wall Street Transparency and Accountability")
- Subindex: *centralized clearing*, submission of derivatives data to a *central repository*, *SEFs*, supervision through SEC and CFTC, *Volcker rule*, *Collins floor*.
- The European "version" of the law is through EU directives: European Markets and Infrastructure Regulation ("EMIR").

Capital for Market & Credit Risk - (1)

- Loosely, capital is the amount of funds that owners of the firm contribute. Acts as a buffer to protect from insolvency when asset values decline.
- These losses can come from *market risk exposure* – i.e., movements in financial variables that affect the value of the bank's holding of securities.
- Or these losses can come from *counterparty credit risk exposure* – i.e., from failures of the bank's counterparties to pay on their obligations.
- As mentioned, capital adequacy regulations are written by agencies such as the Bank for International Settlements (BIS) and local regulators such the FRB, the FSA, etc. BIS drafts the so-called *Basel Accords*, the key methodology prescriptions.

Capital for Market & Credit Risk - (2)

- From a regulatory standpoint, capital held by a bank is tiered into various "quality grades".
  - Tier 1: Common Stock and Retained Earnings.
  - Tier 2: Supplementary bank capital that includes items such as revaluation reserves, undisclosed reserves, hybrid instruments and subordinated term debt.
  - Tier 3: "Everything else" – a greater number of subordinated issues, undisclosed reserves and general loss reserves.
- The regulatory formulas compute "RWA" – Risk Weighted Asset – values for both market risk (RWA_M), credit risk (RWA_C), and operational risk (RWA_O).

Capital for Market & Credit Risk - (3)

- The regulatory capital (RC) requirements then take the form

$$\frac{RC}{\mathrm{RWA}_M + \mathrm{RWA}_C + \mathrm{RWA}_O} \geq X\% \tag{1}$$

  where X depends on the Accord and on time. It is 8% for Basel 2.

- There are also restriction on Tier 1 capital alone. Certain "globally systemically important" banks (G-SIBs) need to post more Tier 1 capital than other banks.
- I'll ignore RWA_O going forward.

Market Risk RWA in a Nutshell - (1)

- Under regulatory capital rules, capital requirements for market risk exposure leans heavily on value-at-risk (VaR) computations, supplemented by add-on charges for so-called *specific risk* (= idiosyncratic event risk for individual firms).
- These computations are fairly "standard", involving 99th percentile return distributions over 10-day horizons.
- Results can often be pulled from banks' regular VaR market risk systems and the computations have traditionally not been complex enough to involve front office quants (they are generally handled by risk management).

Market Risk RWA in a Nutshell - (2)

- While our focus here shall be on credit risk capital, it is worth noticing that the various financial crisis has caused BIS to recently refine/revise its market risk capital requirements substantially.
- Some of these changes has meant an increase in complexity that in many banks has required implementation support by the quant teams.
- In a nutshell, market risk requirement evolution is something like this:

Market Risk RWA in a Nutshell - (3)

- **Basel 1 (1988):** RWA $= 12.5 * m * \text{VaR} +$ specific risk add-on. Here, m $=$ supervisory multiplier ≥ 3.
- **Basel 2 and 2.5 (2004 and 2010):** Add "stressed" VaR to overall VaR requirement. For credit derivatives, add two new measures – Incremental Risk Charge (IRC) and Comprehensive Risk Measure (CRM) – to better measure risk associated with defaults and credit spread dynamics.
- **Basel 3 (2011):** Add VaR on CVA (Credit Value Adjustment). Also, provisions for liquidity risk, leverage ratios, etc.
- **FRTB ("Basel 4") (draft):** Replace VaR with CVaR, avoid double-counting VaR and "stressed VaR", eliminate IRC/CRM,...

IRC/CRM - (1)

- IRC (for CDSs) and CRM (for CDOs) were introduced following the financial crisis, which had regulators concerned about the effects of credit derivatives on financial stability.
- BCBS appeared especially worried about lacking liquidity, and require VaR-type calculations on a 1-year horizon.
- In practice this requires simulation of *all* components that go into valuation of structured credit derivatives books; enough samples to estimate the 99.9% confidence level.
- This requires modeling of: joint dynamics of spreads, defaults, recovery, basis spreads, correlations, ratings, etc. Done by quants in most banks.

IRC/CRM - (2)

- The specification and implementation (and defense) of the simulation model and the portfolio “aging” assumptions was an expensive and lengthy exercise for most US banks.
- AND NOW: Basel 4 eliminates these new charges (starting officially in 2017).

Credit Capital - (1)

- *Regulatory credit risk capital*: standardized regulatory requirements for how much capital banks should hold to protect themselves against counterparty defaults.
- As mentioned, imposed by regulatory agencies such as BIS (Basel), FDIC, FRB, FSA, and so forth.
- *Economic capital*: how much capital a firm should rationally set aside to protect against insolvency from economic credit losses, in the absence of regulatory capital.
- Economic capital is a risk measure (it does not equal actual capital set aside), and is used internally by banks for decision making purposes.

Credit Capital - (2)

- In Basel 1, regulatory credit risk capital is computed in a very simplistic fashion, based on deal notionals and categorization of trades into various buckets. There is no explicit recognition of the rating and recovery of the counterparty.
- This rule, which is still the law in the US, is known as the *Current Exposure Method (CEM)*.

CEM Method - (1)

- Consider a counterparty with several netting sets (NS). Trade j with the counterparty is assumed to have value v_j to the bank.
- CEM method (Basel 1, 1988) writes RWA $= 12.5 \cdot$ EAD $\cdot$ RW, where the risk weight RW is given "in a table", and EAD is

$$EAD = CE + PFE$$

- Here CE (current exposure) is

$$CE = \sum_k \left(\sum_{j \in NS_k} v_j \right)^+$$

- PFE (potential future exposure) is (N_j: notional of trade j)

$$PFE = (0.4 + 0.6 \cdot NGR) \cdot \sum_{\forall j} \alpha_j N_j$$

CEM Method - (2)

- Here *net-gross ratio NGR* is

$$NGR = \frac{CE}{\sum_{\forall j} v_j^+}.$$

- The α_j are heuristic trade-level add-ons, to be looked up in table provided by BCBS. They depend on asset class and maturity.
- Note that CEM, besides being quite heuristic, only recognizes maximum 60% diversification

CEM Method - (3)

- CEM has been criticized – even by BCBS itself – on many grounds, including (from BCBS docs):
  - It does not differentiate between margined and unmargined transactions;
  - The supervisory add-on factors do not sufficiently capture the level of volatilities as observed over the recent stress periods; and
  - The recognition of hedging and netting benefits through NGR is too simplistic and does not reflect economically meaningful relationships between the derivative positions.
- The advanced methods in Basel 2 was introduced in large part to address these issues and to make regulatory credit capital more resemble *economic* capital.
- Recently an improvement to CEM (SA-CCR) was improved for those banks that cannot handle a move to advanced methods.

SA-CCR

- Meant to go into effect in early 2017
- Writes
$$EAD = \alpha(RC + PFE), \quad \alpha = 1.4$$
- RC considers collaterals and margining
- Within each of five asset classes, calculate PFE as
$$PFE = \text{Notional x Delta x Maturity Factor x Supervisory Factor}$$
- Relatively simple and easy to implement, aims to be more risk-sensitive than CEM
- But still not great..

Economic Credit Capital for Loans - (1)

- Assume that a bank has a portfolio of loans with B counterparties. For counterparty i, the net loan notional is assumed to be N_i and the loss-given-default percentage (LGD) is l_i.
- The primary economic risk of interest is here *credit risk*, due to counterparty default exposure.
- Over a period $[0, T]$, the cumulative economic loss due to defaults is

$$L(T) = \sum_{i=1}^{B} N_i l_i 1_{\tau_i \leq T},$$

  where τ_i is the default time of counterparty i, and 1_A is an indicator for the event A (1 if A happens, 0 if it does not).
- The expected value (in the actual probability measure $\mathbb{P}$) of $L(T)$ is denoted the *credit reserve* or the *expected loss* (EL).

Economic Capital for Loans - (2)

- Hence, if $\mathrm{E}(\cdot)$ denotes expectations in $\mathbb{P}$,

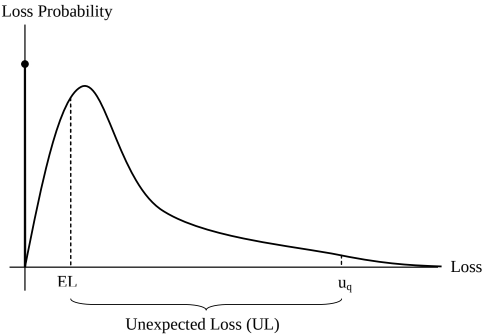
$$EL = \mathrm{E}\left(L(T)\right) = \sum_{i=1}^{B} N_i l_i \cdot p_i, \quad p_i = \mathbb{P}\left(\tau_i \leq T\right),$$

  where p_i is the default probability of counterparty i on $[0, T]$.
- The credit reserve covering EL should be priced into the loans from the outset, and is *not* counted in economic capital. (Regulators do keep an eye on whether banks have adequate provisions for EL).
- Instead, economic capital is designed to sit as a buffer against *unexpected* large losses.

Economic Capital for Loans - (3)

- To characterize large losses, let q be some small probability (i.e. 0.05%), and define the corresponding loss percentile u_q:

$$\mathbb{P}(L(T) \geq u_q) = q.$$



Economic Capital for Loans - (4)

- Economic Capital is set to protect against unexpected losses (UL), so
$$\boxed{EC_q = UL = u_q - EL.} \tag{2}$$
- For a given horizon T (often 1 year), a reasonable way to set q would be based on historical default rates for a target rating or internal grade.
- For instance, to reach an "AA" rating, one equates q to the T-year historical default probability of AA-rated firms ($\approx 0.03\%$, if $T = 1$).
- With this amount of capital, the probability of credit losses wiping out all capital and reserves (and causing bank to go insolvent) would theoretically equal a AA default probability.
- Note: some ratings agencies rely on this principle to rate ring-fenced subsidiaries. To be conservative, it is common to use a worst-case analysis on multiple horizons T.

Computation of EC - (1)

- In principle, the computation of EC_q in (2) can be done by Monte Carlo simulations, where we draw correlated default times for the pool of loan counterparties.
- Default correlation is frequently generated with a one-factor Gaussian copula. Specifically, if the copula correlation is ρ, we set

$$1_{\tau_i \leq T} = 1_{Z_i \leq H_i}, \tag{3}$$

where

$$Z_i = \sqrt{\rho} X + \sqrt{1-\rho}\, \epsilon_i,$$

X is a common Gaussian $N(0,1)$ economy-wide factor, and ϵ_i an i.d. $N(0,1)$ idiosyncratic random variable.

Computation of EC - (2)

- In (3), we obviously need

  $$\mathbb{P}\left(Z_i \leq H_i\right) = \mathbb{P}\left(\tau_i \leq T\right) = p_i,$$

  or

  $$H_i = \Phi^{-1}(p_i),$$

  where $\Phi(\cdot)$ is the cumulative Gaussian distribution function.
- With this, we can generate outcomes of $1_{\tau_i \leq T}$ for all i, which allows us to simulate $L(T)$.
- This, in turn, allows us to compute EC_q from (2)

Large-Portfolio Limits - (1)

- It is common to try to avoid Monte Carlo simulations by using various approximations or by (exact) Panjer recursions.
- For capital computations, the most important technique is the simple *Vasicek large-portfolio limit*.
- The assumption here is simple: there are an *infinite* number B of counterparties.
- In this setup, consider the X-conditional expectation of *per-counterparty* loss (L/B):

$$\lim_{B\to\infty} \mathrm{E}\left(B^{-1}L(T)|X\right) = \lim_{B\to\infty} B^{-1}\sum N_i l_i \mathrm{E}\left(1_{\tau_i<T}|X\right),$$

$$\mathrm{E}\left(1_{\tau_i<T}|X\right) = \mathbb{P}\left(Z_i \le H_i|X\right) = \Phi\left(\frac{H_i - \sqrt{\rho}X}{\sqrt{1-\rho}}\right) = \Phi\left(\frac{\Phi^{-1}(p_i) - \sqrt{\rho}X}{\sqrt{1-\rho}}\right)$$

Large-Portfolio Limits - (2)

- We need some assumptions about the portfolio composition to allow us to form a meaningful large-B limit.
- For instance, if the portfolio is *homogeneous* with all $p_i = p$ and $l_i = l$ identical, the limit exists and we get

$$\lim_{B\to\infty} \mathrm{E}\left(B^{-1}L(T)|X\right) = Nl\Phi\left(\frac{\Phi^{-1}(p) - \sqrt{\rho}X}{\sqrt{1-\rho}}\right) = Nl \cdot h(X).$$

- In the homogeneous case, it is easily seen that

$$\lim_{B\to\infty} \mathrm{Var}\left(B^{-1}L(T)|X\right) = 0,$$

so in large-B limit, we diversify away all idiosyncratic risk not originating from X. And therefore we simply have:

$$\lim_{B\to\infty} L(T)/B = Nl \cdot h(X).$$

Large-Portfolio Limits - (3)

- We therefore have, for large B,

$$\mathbb{P}\left(L(T)/B \geq x\right) = \mathbb{P}\left(h(X) \geq \frac{x}{NI}\right) = \Phi\left(\frac{\Phi^{-1}(p) - \sqrt{1-\rho}\,\Phi^{-1}\left(\frac{x}{NI}\right)}{\sqrt{\rho}}\right) \tag{4}$$

- We can compute EC_q *per counterparty* as

$$EC_q/B = u_q - EL/B = u_q - pNI,$$

where the percentile u_q is given by $\mathbb{P}\left(L(T)/B \geq u_q\right) = q$.

- Using (4), we get the *large-portfolio economic capital formula*

$$\boxed{EC_q/B = NI \cdot \left\{\Phi\left(\frac{\Phi^{-1}(p) - \sqrt{\rho}\,\Phi^{-1}(q)}{\sqrt{1-\rho}}\right) - p\right\}}. \tag{5}$$

Non-Loan Portfolios - (1)

- We emphasize that (5) is only an approximation of per-counterparty EC, and does not (so far) cover anything other than loans.
- We now up the ante and consider the more challenging situation where our exposure to a counterparty is not generated by loans alone, but by a complex portfolio of securities.
- Let $V_i(t)$ be the promised (default-free) time t value to the bank of counterparty portfolio i, and let $C_i(t)$ be the (stochastic) collateral value posted by the counterparty.
- The stochastic *exposure* at any t is (ignoring close-out risk, for now)

  $$E_i(t) = (V_i(t) - C_i(t))^+.$$

  Unlike CVA, for capital we only consider the bank's exposure to counterparty (not vice versa).

Non-Loan Portfolios - (2)

- Positive exposure combined with a default of counterparty i will lead to a credit loss of $l_i E_i(\tau_i)$.
- Therefore,

$$L(T) = \sum_{i=1}^{B} l_i E_i(\tau_i) 1_{\tau_i \leq T}. \tag{6}$$

- This is similar to the loan setting from earlier, except that the loan notionals (N_i) are now random numbers (E_i).
- Economic capital is still computed as before, $EC_q = u_q - EL$, but both u_q and EL are now more complicated to compute.

Non-Loan Portfolios - (3)

- A (naive) simulation algorithm could work like this:
  1. Simulate in $\mathbb{P}$ a path of correlated market data (rates, equities, commodities, spreads, FX,...) out to time T. Let $\omega(t)$ be the market data state at time t and prior.
  2. Generate a set of correlated default times τ_i, $i = 1, \ldots, B$.
  3. At time τ_i (if less than T), use $\omega(\tau_i)$ with pricing analytics to establish $V_i(\tau_i)$ and $C(\tau_i)$, $i = 1, \ldots, B$.
  4. Establish $L(T)$ from (6).
  5. Repeat for many paths, to uncover full distribution of $L(T)$.
- Equipped with the simulated loss distribution, we can establish EC_q.
- This can be a very challenging/time-consuming exercise, especially if q is small and if the portfolio is complex and expensive to price.

Basel 2 and IRB - (1)

- Key objective of the *internal ratings-based* methodology (IRB) in Basel 2 is to provide a framework for regulatory credit risk capital that is spiritually similar to economic capital.
- However, the IRB needs to be sufficiently simple and transparent to be used in a regulatory setting.
- A special requirement by regulators is *portfolio invariance*: the capital treatment given to a loan position with a given counterparty should be identical from one bank to the next, and should not depend on exposure to other counterparties.
- This is accomplished by assuming *infinite diversification*, in the same manner as we did for the large-portfolio EC result.

Basel 2 and IRB - (2)

- In addition, to avoid the complexities of joint market and default simulations, regulators wish to decouple exposure and default simulations by introducing the concept of *loan-equivalent notional* (LEN) a.k.a. *exposure-at-default* (EAD).
- The idea behind EAD is to take a securities portfolio and replace it in some fashion with a simple loan. After this, the Vasicek formula for loans is applied directly.
- We shall return to how EAD is computed later. Let us first discuss some modifications that Basel 2 makes to the Vasicek economic capital formula (5).

Basel 2 and IRB - (3)

- First, correlation is made a decaying function of default probability p, in an attempt to fit historical observations for asset correlations across various economic cycles. (???)
- Second, regulators wish to introduce a component of *transition risk*, i.e. the risk of market value losses due to counterparty ratings deterioration (i.e. spread increases) over the interval $[0, T]$, even when there are no outright defaults.
- Such transition risk increases with the spread duration of the portfolio exposure, so Basel 2 also needs a methodology for computing a loan equivalent *effective maturity* (M). We discuss this later.
- The transition risk adjustment to regulatory capital (RC) takes the form of a scale function $k(M, p)$ that depends on effective maturity M and default probability p.

Basel 2 and IRB - (4)

- As in Basel 1, one writes $\mathrm{RWA}_C = 12.5 \cdot RC$ where the *key formula* for regulatory capital (RC) for a counterparty-level trading position:

$$RC_q = EAD \cdot RW, \tag{7}$$

$$\boxed{RW = l \cdot \left\{ \Phi\left(\frac{\Phi^{-1}(p) - \sqrt{\rho(p)}\Phi^{-1}(q)}{\sqrt{1-\rho(p)}} \right) - p \right\} \cdot k(M,p)}, \tag{8}$$

  and:

  - p: 1-year probability of default (PD);
  - l: loss-given-default percentage (LGD);
  - q: 0.001 ("once in a thousand years");
  - M: effective maturity;
  - $\rho(p) = 0.24 - 0.12(1 - e^{-50p})$ (ignoring small-firm terms)

Basel 2 and IRB - (5)

- The transition risk adjustment function k is:

$$k(x,y) = \frac{1 + (x - 2.5)b(y)}{1 - 1.5b(y)},$$
$$b(y) = (0.11852 - 0.05478 \ln y)^2.$$

- The function k is complex, and the way it has been arrived at is not completely transparent.
- BIS documents hint at the usage of VaR computations using a ratings-based MtM credit risk system similar to KMV PortfolioManager, but details are not disclosed. "Black Box".

Basel 2 and IRB - (6)

- The inputs to the RC computation in (7) are: EAD, LGD, PD, and M.
- Because EL and UL emerge in a clean portfolio-invariant fashion from obligor-specific characteristic (PD and LGD), the RC approach is considered purely *ratings-based*, hence the IRB moniker.
- At most banks, a dedicated capital management team is responsible for the estimation of LGD and PD. The methodologies are actuarial in nature, and must be approved by regulators.
- The capital management teams are generally also responsible for the ultimate reporting of RC numbers produced by (7).
- However, it is becoming increasingly necessary to have quant teams execute the computations for EAD and M, a topic that we return to shortly.

FIRB vs AIRB

- Depending on where EAD, LGD, PD and M come from, we have two IRB approaches: Foundation IRB and Advanced IRB (FIRB and AIRB)
- In FIRB, EAD is computed by CEM (see earlier slide) and LGD, M are provided by regulatory rules. PD must be estimated by bank itself.
- In AIRB, all quantities are provided by the bank itself, subject to examinations (for each quantity separately) by regulators.
- All large banks are expected to use AIRB.

PD - (1)

- It would be tempting to pick PDs from traded securities, such as CDSs. Apart from the fact that such information is only available to a very small set of obligors, recall that we need default probabilities in the actual probability measure $\mathbb{P}$, not in a risk-neutral measure.
- PD formally is:

> *"[T]he long-run average one-year default rate for the rating grade assigned [...] to the obligor, capturing the average default experience for obligors in the rating grade over a mix of economic conditions.."*

- Specialized risk rating teams at banks are charged with assigning each counterparty to an internal *obligor risk rating* (ORR), an internal scale (e.g., from 1 to 10).

PD - (2)

- Assigning an ORR to an obligor is often based on fundamental analysis ("scorecards") similar to that undertaken by rating agencies.
- In fact, rating agency ratings (when they exist), are taken into account in the ORR, but supplemented by bank's own data and methodologies.
- PD is not easy to estimate, and bank methodologies vary. There have been controversies, for instance (Risk Magazine, June 2013)

> *"Danske Bank and its regulator were pitched into open conflict in mid-June, when the Danish Financial Supervisory Agency told the bank to hold more capital for corporate loans. [...] The primary driver of the seemingly anomalous risk weights is the bank's consistently low PD estimates, [...] although low LGD numbers also play a role. "*

LGD

- *"A bank must estimate an LGD for each facility that aims to reflect economic downturn conditions where necessary to capture the relevant risks. This LGD cannot be less than the long-run default-weighted average loss rate given default [...]"*
- Regulators want banks to use LGDs that are higher than average, to reflect the fact that LGDs tend to increase in a systemic crisis. Can be done by emphasizing data from periods where credit losses are higher than normal.
- "Downturn" LGDs are estimated by capital management teams using historical default and recovery data.
- The estimation often involves several factors, primarily the *collateral type* and *line of business*.

EAD and M

- The computation of EAD and M is governed by a regulatory framework called *internal models methodology* (IMM) and is normally handled by a counterparty credit risk function, along with assistance from technology and, increasingly, front office quants.
- EAD computations are complicated and model intensive, so banks have to establish very robust controls and oversights around their computations.
- In addition, rigorous backtesting procedures are required to prove that the models used for exposure computations are realistic and conservative. Models must be approved by model validation.
- Formal submission to regulators and passing an examination with the OCC/FRB is required to be approved for IMM and Basel 2.