Structured RAY

Risk-Adjusted Yield for Securitizations and Loan Pools

Market Yields for Mortgage Loans

- The mortgage loans over which the R and D scoring occurs have risk characteristics that investors would like to quantify in terms of market yield.
- Market yields are quoted in many conventions, based on various scenarios different investors can run.
- To normalize across all possible investor scenarios, we quantify all mortgage loan risk with an associated risk-adjusted yield, which accounts for the voluntary and involuntary risk components, as well as market-expectations of additional risk.
- The following slide describes the mathematical framework under which we capture the above risks into a risk-adjusted yield (RAY).

Structured RAY for Securitization and Loan Pools

- Structured RAY pool-level, loan-level, and tranche-level analytics serve as cutting-edge ranking attributes for “Agency” (Fannie Mae, Freddie Mac, and Ginnie Mae) backed mortgage-backed securities (MBS).
- The Structured RAY determines the intrinsic riskiness of the assets through a yield analysis, driven by R-score ranks the voluntary prepayment behavior and D-score ranks the involuntary prepayment behavior.
- The Structured RAY paired with the quantum modeling framework offers a host of associated pool-level analytics to manage the agency MBS risks, including interest rate, home price index, credit cycle, turnover, refinance, cash-out, buyout, and curtailment.

Mortgage Loan Risk-Adjusted Yield (RAY)

- Mortgage Risk-adjusted Yields are established in order to quantify the risk-reward relationship for a given mortgage loan, based on the intrinsic credit/prepay factors, as well as market-driven factors such as liquidity, regulatory risk, counterparty risk, and maintenance carry.
- In addition to Risk-adjustment, our latest version of RAY (called the Structured RAY) also accounts for the credit convexity that can occur within structured products such as Agency MBS, Non-Agency MBS, P2P deals, CMBS, Project Loans, and all other securitizations!
- In order to determine the Structured RAY for our set of loans, we use the following mathematical formulation to obtain yields that match current market-calibrated levels:

Structured RAY Formulization

- `RAY = MktYld_calib + [MinRiskFactor - (InvolPrepayRiskFactor + VolunPrepayRiskFactor)/(InvolPrepayRiskMin + VolunPrepayRiskMin)]*MktVol_calib,` such that:
  - MktYld is the baseline yield for that origination/pool calibrated from market data.
  - MinRiskFactor is the lowest risk factor (e.g. highest score) that can be obtained in such origination/pool
  - InvolPrepayRiskFactor is the individual mortgage loan's <u>involuntary</u> prepay risk factor (higher number indicates lower risk) – this is where we utilize **D-Score**
  - VolunPrepayRiskFactor is the individual mortgage loan's <u>voluntary</u> prepay risk factor (higher number indicates lower risk) – this is where we utilize **R-Score**
  - InvolPrepayRiskMin and VolunPrepayRiskMin are the factors where the lowest risk for involuntary and voluntary risk would occur (highest sum indicates lowest risk)
  - MktVol is the volatility factor for the difference in loan risk versus "ideal risk" and is calibrated from market data.

Structured RAY is Credit-Adjusted <u>and</u> Risk-Adjusted Yields (Total Return)

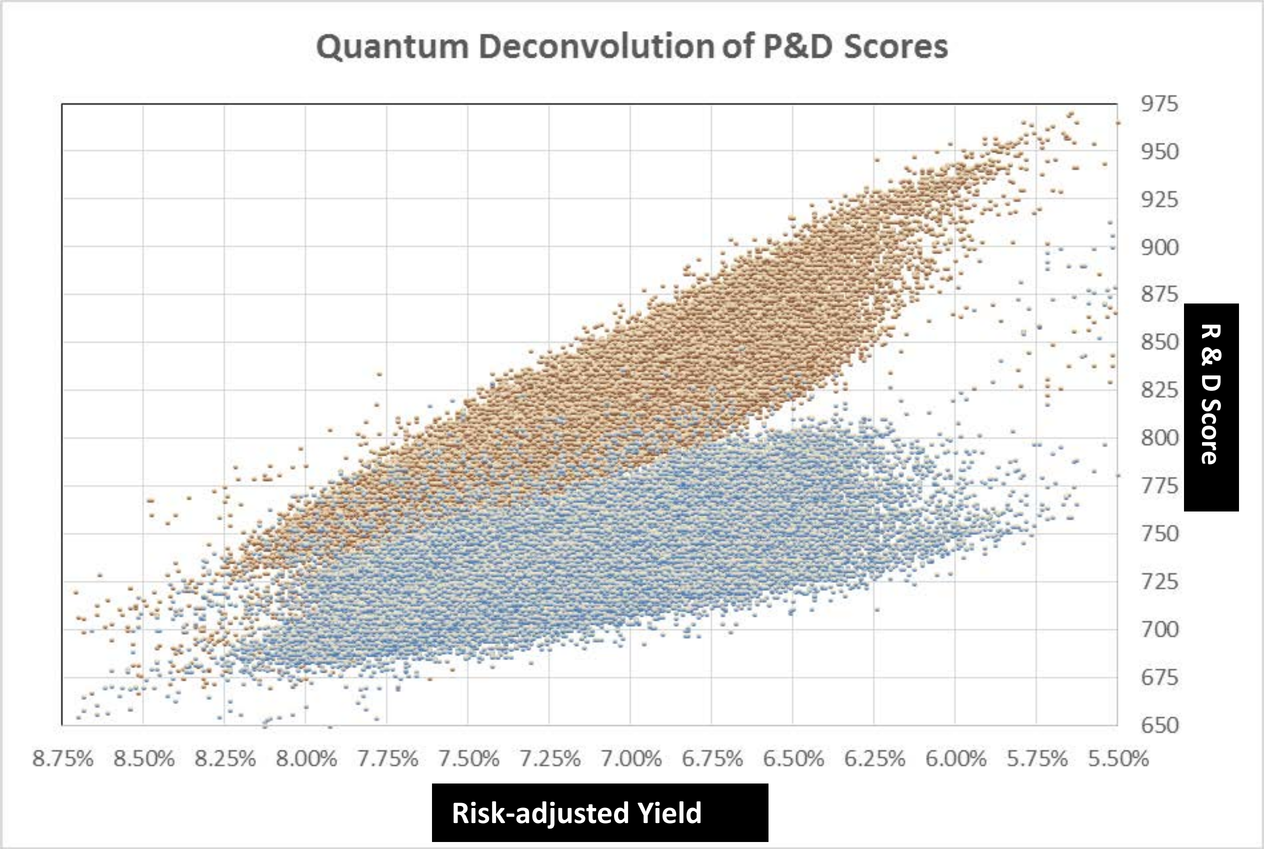
- The individual mortgage loan Risk-Adjusted Yields can be transformed into securitization bond yields, once the loans are pooled into an MBS cohort.
- Structured RAY not only adjusted for intrinsic risk, but also credit-adjustment given the asset’s “structured position,” derived based on the following metrics, one the pool-level RAY is determined:
    - Credit Enhancement (Subordination, OC, XS) adjustment
    - Rating adjustment
    - Pool Diversification adjustment
    - Pool Prepay Correlation adjustment
    - Pool Default Correlation adjustment
    - Servicer Quality adjustment
    - Agency Guaranty Adjustment
    - Duration/DV01 Adjustment
    - Credit/CS01 Adjustment
    - Convexity Adjustment

Optimization of RAY

- Using underlying loan-level scoring as reliable mortgage risk measures, we can then determine a risk versus reward profile, where the reward is determined based on the market risk-adjusted yields.
- The efficient frontier theory, as formulated by Markowitz and Schwartz, proposes that the optimal assets can be selected by their relationship of risk to reward.
- In simplistic terms, the efficient frontier is the region of risk-reward space where all your assets are most optimal. If you choose an asset that falls below the efficient frontier red line, you have chosen a non-optimal risk-reward relationship, which can cause extreme investment losses potentially.

Quantum Deconvoluted Risk-Adjusted Yields

- In order to derive the separate Efficient Frontiers for R and D scores, we first show the quantum deconvolution plot of R and D scores with their respective Risk-adjusted yields, over every Agency loan data point!

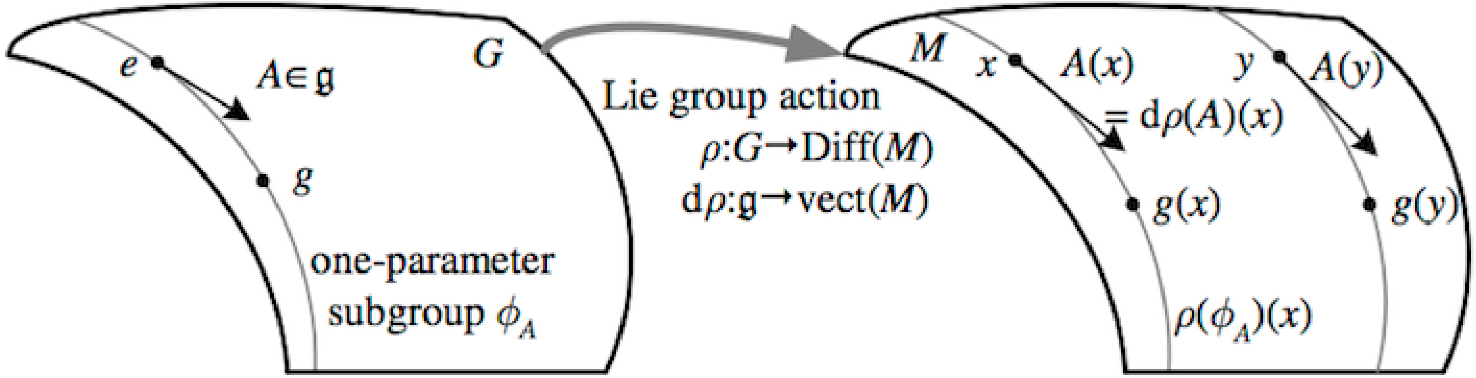


RAY Implied Convexity

- Unlike the R-Score efficient frontier, we can clearly see that the D-score risk-reward space exhibits much less convexity with respect to risk-adjusted yields.
- This means that D-Score are not as sensitive to interest rates, which intuitively makes sense because D-Score is actually capturing CREDIT and DEFAULT relationships that lie within the loan characteristics, independent of interest rate environment.
- R-Score convexity is also intuitively makes sense because the voluntary prepayment is highly correlated to the interest rate convexity.
- Therefore, not only do the R and D scores allow traders, investors, and portfolio managers to select the most optimal mortgage loans, it also defines the convexity profile within the loan pool for both voluntary and involuntary prepayment risk!

Lie Groups within Financial Manifolds

- KDS's quantum deconvolution framework derives symmetries through Lie Group derivation, such that a Lie group is a smooth manifold obeying the group properties and that satisfies the additional condition that the group operations are differentiable.
- They are used as a representation of mathematical structures and objects continuous symmetry, serving as an analysis of quantum differential space.
- Our proprietary Lie algebras replace the global understanding of prepayment (the group with its linearized and local version).



Quantum Deconvolution using Lie Algebras

- Differential manifolds provide random and nonlinear interest rate behavior, which has tremendous implications to prepayment (voluntary and involuntary) via stochastic differential geometry, which evolves on a curved state space.
- The underlying curved space keeps volatility and drift simple and also offers a global description of credit (borrower-sensitive) and prepayment (rate-sensitive) valid over a wide range of tail events and stochastic scenarios.
- For example, the Riemannian geometry can be formulated elegantly as the integral curves that minimize the squared length

$$J(U) = \int_0^1 \langle U(t), U(t) \rangle_g \mathrm{d}t,$$

subject to the matrix condition

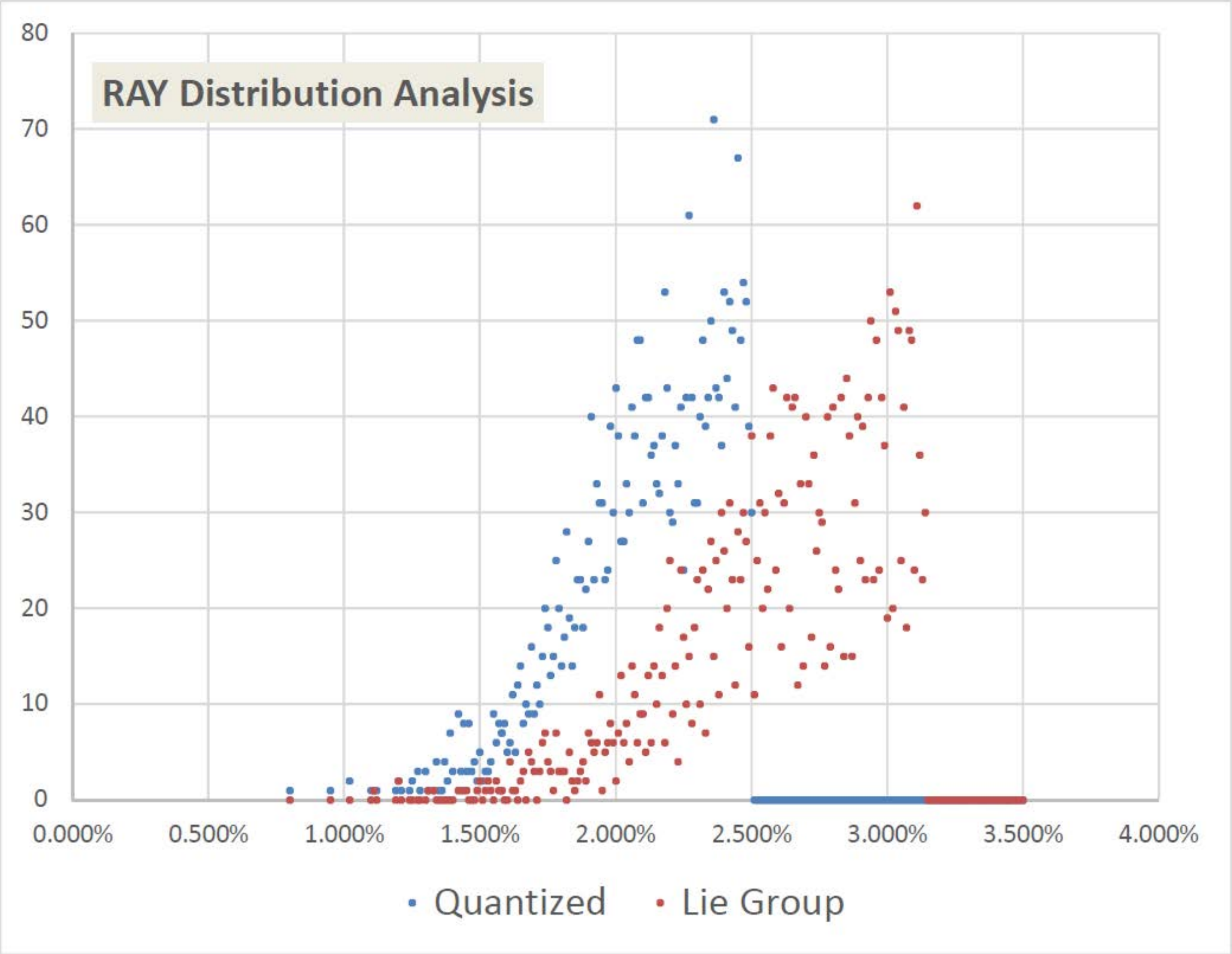
$$\dot{X}(t) = X(t)U(t),$$

Quantum Diffusion Process to Model Underlying (Loan-Level) Factors

- Our RAY framework also models the intrinsic diffusion processes that physically describe the dispersion of risk and volatility over time. It is a solution to a stochastic differential equation.
- It is also referred to as a continuous Markov process $X = X(t)$ with transition density $p(s, x, t, y)$ which satisfies the following condition: There exist functions $\alpha(t, y)$ and $\sigma^2(t, x)$, known as the drift coefficient and the diffusion coefficient respectively, such that for any $\epsilon > 0$

$$\left.\begin{aligned}
&\int_{|y-x|=\epsilon} p(t, x, t+\Delta t, y)\,dy = o(\Delta t),\\
&\int_{|y-x|\leq\epsilon} (y-x)\,p(t, x, t+\Delta t, y)\,dy =\\
&\qquad = \alpha(t, x) + o(\Delta t),\\
&\int_{|y-x|\leq\epsilon} (y-x)^2\,p(t, x, t+\Delta t, y)\,dy =\\
&\qquad = \sigma^2(t, x) + o(\Delta t),
\end{aligned}\right\}$$

Structured RAY Distributions in Quantized and Lie Group mapping



ATOMS™ RAY

- ATOMS™ Risk Adjusted Yield (RAY) is derived from the underlying around 200,000 ATOMS MBS cusips daily updated market implied price (MIP).
- ATOMS™ Intrinsic Value (AIV) is the duration adjusted price, which is affected by the ATOMS™ R Score (voluntary prepayment risk), D Score (Involuntary prepayment risk) and a multiplier factor derived from optimizing the minimum difference between MIP and AIV.

Market Implied Price (MIP)

- We used secant method to calculate from Market Implied Price (MIP) to RAY, which is a root-finding algorithm that uses a succession of roots of secant lines to better approximate a root of a function f(x).
- The secant method can be thought of as a finite difference approximation of Newton's method.

$$f(x) = \frac{(100 + Duration \times Coupon)}{(1+x)^{Duration}} - MIP$$

$$x_{i+1} = x_i - f(x_i) \times \frac{(x_i - x_{i-1})}{f(x_i) - f(x_{i-1})}$$

We used 3.85% (x1) and 3.90% (x2) as two initial approximations and minimum duration condition is > 2.

How AIV is Calculated

$$\textbf{ATOMS}^{\text{TM}}\ IntrinsicValue = 100 \times (1 - Duration \times (Multiplier \times LoanRay - Coupon))$$

Where *Multiplier* is optimized by the minimum difference between MIP and AIV.

Where *LoanRay* is:

$$LoanRay = BaseRate + (NormalizedMinRiskFactor - \frac{LoanRscore + LoanDscore}{Max(LoanRsore) + Max(LoanDscore)} \times MktVol\%)$$

Where *MktVol%* is:

$$MktVol\% = \sqrt{CV_{Rscore}^{2} + CV_{Dscore}^{2}}$$