Rating Residential Mortgage-Backed Securities (RMBS)

Residential Mortgage-Backed Securities (RMBS) were the original structured security type. The U.S. bank market had been undergoing significant structural changes associated with deregulation and modernization beginning in the late 1960s, and hit by rising interest rates in the late 1970s. When the U.S. Federal Reserve raised the discount to 12% in 1979, a large number of mortgage lenders became insolvent but their loans were of a high quality. Securitization was invented to buy these loans out of portfolio for on-sale to third party investors.

Early RMBS were only sensitive to pre-payment risk, not to credit risk. Many different security types, called CMOs, were crafted to cater to different interest rates. After the mid-1990s, mortgage lending expanded down the credit Spectrum, and credit risk became a permanent feature of RMBS, making them no different in principle than ABS.

Spectrum's RMBS approach belongs to our backbone methodology in I Spectrum Credit Rating Framework. We model loan pools of the following payment and interest type: regular, fully amortizing loans; loans with interest-only periods; balloon loans; bullet loans; and hybrid graduation payment loans, with fixed, floating or mixed rates. We model the capital structure precisely in accordance with the waterfall from the documentation provided to us.

1) Minimum Required Collateral Data Set

To comprehensively describe payment behaviors under loans, our minimum dataset consists of these dimensions:

Table 1 – Minimum RMBS Dataset

Variable Name (unit)	Symbol
Initial Balance ($)	P_0
Current Balance ($)	P_c
Balloon Balance ($)	P_b
Periodic Percentage Rate (%)	r
Interest Rate Type (fixed/floating)	T_I
Original Term (months)	T
Remaining Term (months)	T_r
Original IO Period (months)	T_{IO}
Fixed to Floating Term (months)	T_{FF}
Hybrid Graduated Payment Loan (true/false)	HGPL
HGPL Alpha (%)	A
HGPL Time Alpha (month)	T_α
Delinquency Status (#)	D
Origination Date	t_l
Wholesale Value at Origination ($)	W_0
Credit Score	S

2) Modeling Loan Cash Flows

by Loan Type

More than one type of mortgage loan can be found in RMBS transactions. Simulating the amortization of loan cash flows must follow the loan type and schedule. The algebra of modeling the most commonly featured loan types is set forth below. Variations must follow these norms:

1- Regular fully amortizing loans: Calculate the fixed monthly payment for a loan using current balance, interest rate and remaining term, as follows:

$$M = \frac{P_c r}{1 - (1+r)^{-T_r}}$$

2- Loans with interest-only (IO) period: Calculate loan payments using the loan balance and original IO period. One of two cases is possible:

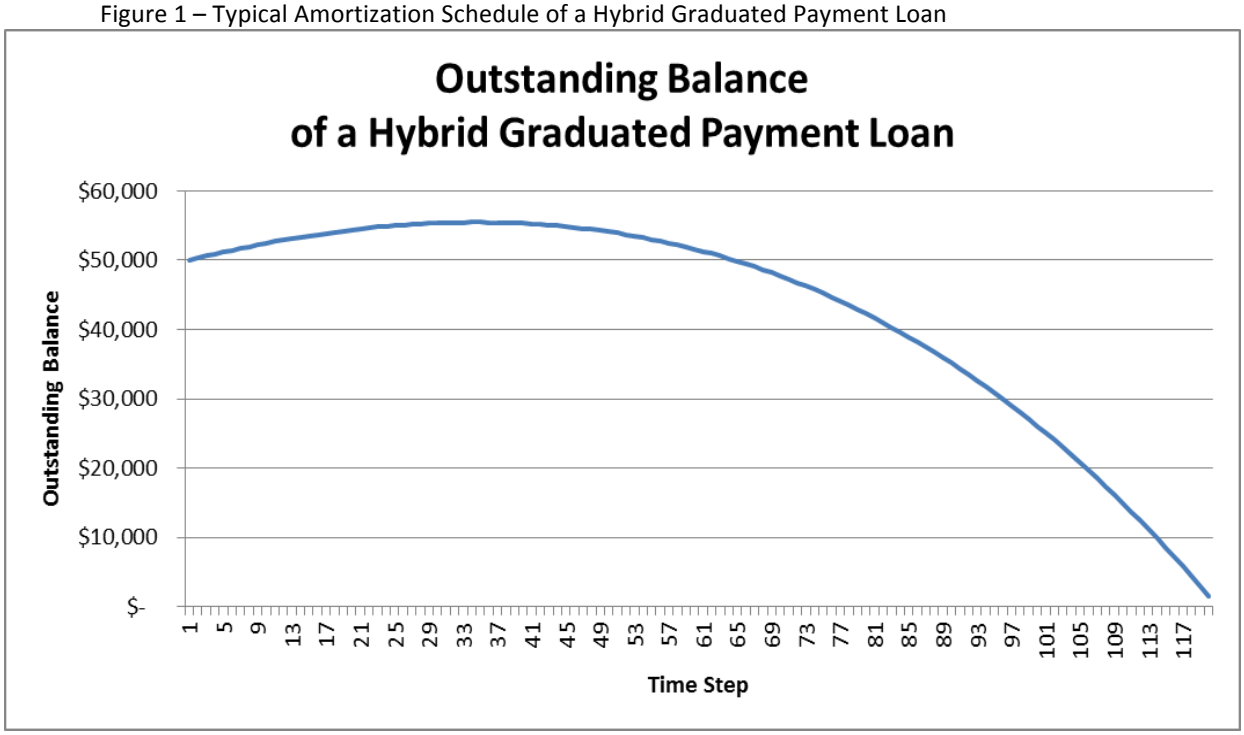
   i. Loan is still in the IO period at the time of securitization. The loan will have monthly payments equal to the interest payment on the original balance until the IO period is over. At the end of the IO period, compute the fixed monthly scheduled payment that is sufficient to fully amortize the original balance of the loan over the period equal to the difference of original term and IO term
   ii. Loan has already started amortizing at the time of securitization. Then, calculate the fixed monthly scheduled payment using current balance and remaining term as described in 1).

3- Balloon loans have a fixed monthly scheduled payment sufficient to amortize the loan from the original balance to the balloon balance. The last payment is equal to ***M,*** regular monthly scheduled payment + balloon balance.

4- Bullet loans are a combination of IO period and final balloon payment. The IO period is one month shorter than the original period. The balloon balance equals the original balance.

5- Hybrid graduation payment loans formulas need two additional parameters – alpha, a negative amortization parameter representing the target maximum accretion percentage of the original loan balancel and the time step when the new balance should be reached. HGPL principal balance first rises and then amortizes.

Figure 1 – Typical Amortization Schedule of a Hybrid Graduated Payment Loan



Error Flagging

With so many formula parameters, the pool cut amortization schedule is error-prone. For this reason, Spectrum has implemented a number of automatic data integrity checks. When a pool cut containing loans with impossible conditions is entered into the system, e.g., a loan still in the IO period whose current balance is smaller than the original balance, an automatic error message is generated. The analyst cannot proceed until the error is corrected.

3) Time Dynamics in RMBS

There are two different time scales to keep in mind when modeling the cash flows of any given transaction:

a) The time of the loan
b) The time of the securitization transaction

Mortgage pool cuts often contain loans that have been outstanding for considerably different amounts of time than transaction initiation. The gap between loan origination and loan securitization, seasoning, can be sizable and must be adjusted for.

4) Payment Dynamics in RMBS

The three most important aspects of loan repayment, namely the dynamics of delinquencies, losses and prepayments, all develop on the timescale of the loan. Each loan must be modeled accordingly, and separately.

Deriving the Markov Delinquency-Transition Matrix

Spectrum uses a non-stationary Markov-matrix formalism to investigate the impact of delinquency transition on the portfolio's credit quality. The analysis begins by requesting minimally the most recent 13-month delinquency history of a fairly large loan-sample drawn from the sponsor's managed portfolio.

Figure 2 – Markov Transition Matrix in a Typical RMBS Transaction

Loan-By-Loan Valuation : Markov Transition Matrix

Import Export Close

	Current	30 days	60 days	90 days	Prepays	Defaults
Current	98.89%	0.10%	0.00%	0.00%	1.01%	0.00%
30 days	5.00%	35.00%	60.00%	0.00%	0.00%	0.00%
60 days	0.00%	5.00%	15.00%	80.00%	0.00%	0.00%
90 days	0.00%	0.00%	1.50%	8.50%	0.00%	90.00%
Prepays	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Defaults	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

RMBS

RMBS Prepayment Model

SMM Alpha 1.0 SMM Beta 7.0 SMM A 7.0 SMM Sigma 0.07 CIR

Turning the sample into a robust delinquency-transition matrix is a fairly routine procedure. The matrix is derived as a unit-matrix based on the loan account transition matrices—not dollar accounts, which are nonergodic. This is the "base" matrix for the delinquency operator, to be modulated by the unit-default curve (next section) as part of the calibration of pool micro-dynamics to the expected default rate (EDR), computed separately.

The result will resemble Figure 2 above. Integers correspond to the number of delinquent months and "D" means that the loan has been declared in default using the definition in the underwriting guidelines. Here, the credit policy-defined default is 91+ days pastdue. Once a given unit-transition between delinquency states becomes known at any time step, Spectrum uses a cash flow transfer function to turn the latter into a cash flow event.

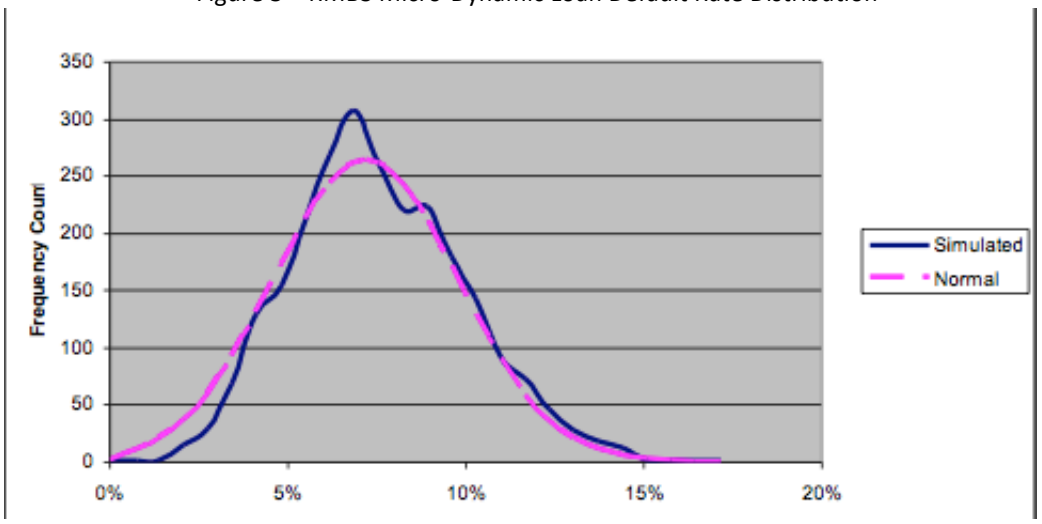
Cash flow transfer functions are reverse-engineered from the sponsor's credit policy manual. If the sponsor is operating without a written credit policy manual, the lead analyst may decide to initiate additional due diligence to determine the reliability of the data history provided. Implementing details are provided in ***Elements of Structured Finance,*** Chapter 15.

Computing the Pool's EDR

The most significant credit driver of the structured transaction is the expected default rate (EDR). Because the target pool may contain loan-assets with markedly different terms than in the sponsor's managed portfolio, the EDR should be computed from the same delinquency-transition dataset used to derive the Markov-matrix.

Using the same delinquency-transition data, Spectrum analysts simulate the one-year cumulative default process using a sufficiently large sample of accounts, usually minimally 1,500. This process leads naturally to the one-year unit-default rate distribution, as represented below:

Figure 3 – RMBS Micro-Dynamic Loan Default Rate Distribution



The obligor independence assumption makes the distribution Gaussian. Its mean default rate is multiplied by the pool average life to derive the target pool expected, cumulative default rate, per Figure 3. By this technique, the analyst can customize the analysis for this deal by linking historical delinquency patterns to the target pool.

As a reminder, the pool's average life t^a is given by:

$$t^a = \frac{T}{1-(1+r)^{-T}} - \frac{1}{\ln(1+r)}$$, whereby

$$T = WAM \text{ and } r = \frac{WAC}{12}.$$

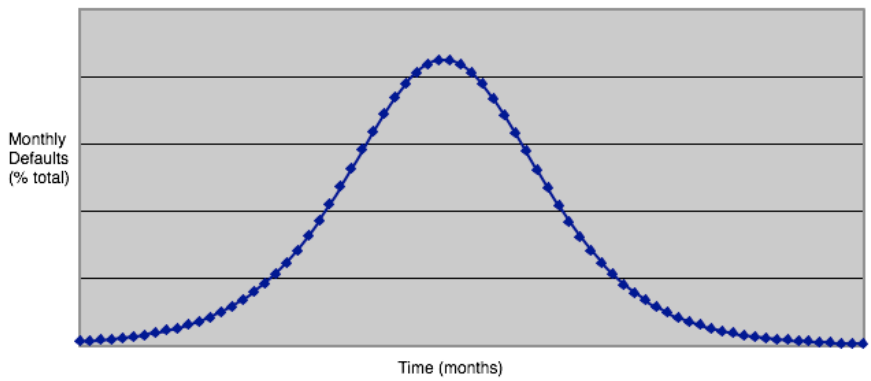
The quantities on the right hand side of the definitions of T and r are the pool's (assumed monthly) weighted average coupon (WAC) and weighted average maturity (WAM), respectively. In all cases, the weights are remaining loan principal balances to be securitized.

Credit Loss Micro-Dynamics

After deriving the pool EDR as above, the next step is to calibrate the pool's default micro-dynamics. This step is necessary because the standard Markov transition-matrix will not, by itself, lead precisely to the required average cumulative default rate. It cannot happen in theory because the target pool has never been securitized. Thus, micro-calibration is required to ensure concordance with the target pool's expected default rate.

Calibration is done by adjusting one parameter from the idealized, marginal loss curve (Figure 4) in real time to make a cumulative default rate distribution with the same average as that derived from sponsor data.

Figure 4 – Typical RMBS Micro-Dynamic Loan Default Rate Distribution



The loan-default analysis begins with the conceptualization of defaults *via* the logistic curve. In equation (1) below, $m(L_e)$ is the micro-calibration parameter:

$$F(t) = \frac{M_p(n)m(L_e)}{1 + b\,e^{-c(t-t_0+t_s)}} \qquad (1)$$

It is adjusted as part of a root-locus method (a stabilizing feature in control systems) to ensure that the target pool's default micro-dynamics concur with the empirically derived, cumulative dollar-default rate distribution.

The marginal default curve below is computed from the equation (1) *via* differentiation with respect to time:

$$f(t) \equiv \frac{\partial F(t)}{\partial t} = \frac{M_p(n)m(L_e)b\,c\,e^{-c(t-t_0)}}{[1 + b\,e^{-c(t-t_0)}]^2}$$

Credit Loss Macro-Dynamics

The most critical step in the rating process on the asset side to determine the macro-dynamics, because the differentiation in tranche ratings ultimately depends on macro-economic risk, not the microrisk of the pool. Spectrum's approach currently relies on a one-factor Clayton copula formalism. This formalism is derived from a Laplace-transform of the standard Gamma distribution function, expressed simply as:

$$g(s) = (1+s)^{-\gamma} \qquad (2)$$

Its implementation is straightforward:

1- From a sample of N loans, select nominally independent, uniform random variables $u_i, i \in [1, N]$

2- Transform the random deviates into the set $x_i, i \in [1, N]$ of correlated variables *via* Clayton modulation:

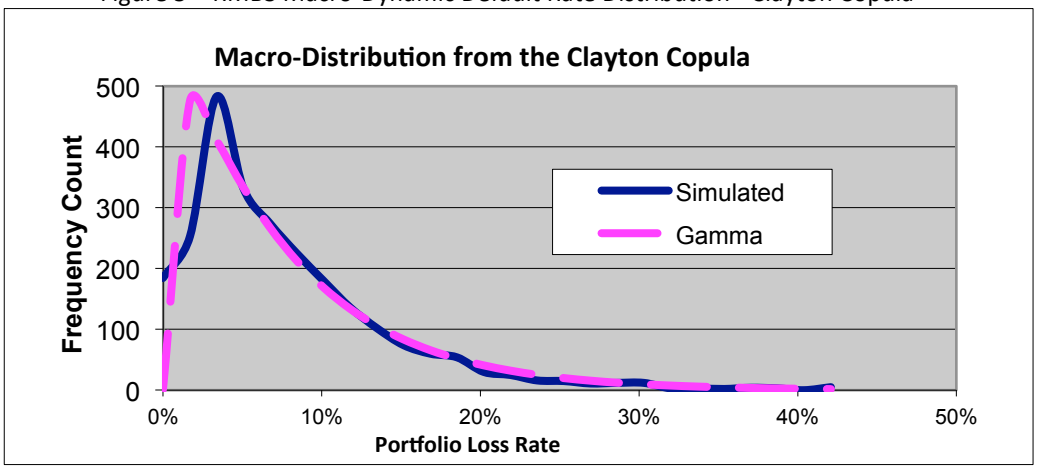
$$x_i = g(-\frac{1}{y}\ln(u_i))$$

3- This procedure correlates the originally-independent default events to individual obligors, causing the original Gaussian default-distribution to spread out from both ends and acquire the familiar skewed shape of Figure 5 associated with the loss distribution.

4- The resulting functional form can best be mapped to a Gamma distribution**.** It should naturally have a mean of 1.0. Any material deviation from 0 may be resolved by nenormalization.

5- A mapping example is constructed in Figure 5:

Figure 5 – RMBS Macro-Dynamic Default Rate Distribution - Clayton Copula



6- Finally, select a single random number from the Gamma-like distribution for each Monte Carlo (MC) scenario in the rating process. This is the macro-parameter $M_p(n)$, where n refers to the current MC scenario.

7- Thus, Spectrum's rating algorithm can generate credit losses in a range sufficiently high to cause security losses in accordance with the proposed bond structure.

Prepayment Modeling

The prepayment characteristics of residential mortgages are subject to multiple dependencies that need to be incorporated into a model in order to obtain a realistic prepayment forecast. The most obvious factor is the average interest rate on the market. Lower rates may motivate a borrower to refinance if the interest cost savings appears to outweigh the refinancing costs. Net-net, these dynamics will cause the pool to amortize faster.

Another aspect of prepayment behavior is burnout. Borrowers most eager and able to refinance are going to leave the pool at the earliest possibility. Should the rates drop again later in the life of transaction refinancing speeds will be significantly lower the second time, since only borrowers less able to refinance will be left in the pool. This dynamic has credit implications and can lower the amount of spread available as credit enhancement.

Another important factor is turnover, which represents prepayments from sales of existing housing stock. It is the most stable component of prepayments, mostly influenced by such factors as property type, borrower aging, seasonality, price appreciation, etc. and only weakly sensitive to the change in level of interest rates.

Taking these factors into account, Spectrum models prepayments in the Markov transition matrix (Figure 2) by changing the entry in the second to last column of the first row of the matrix, the probability that the loan current last month will prepay this month. This probability changes every time step and individually for every loan in the pool via this prepayment function:

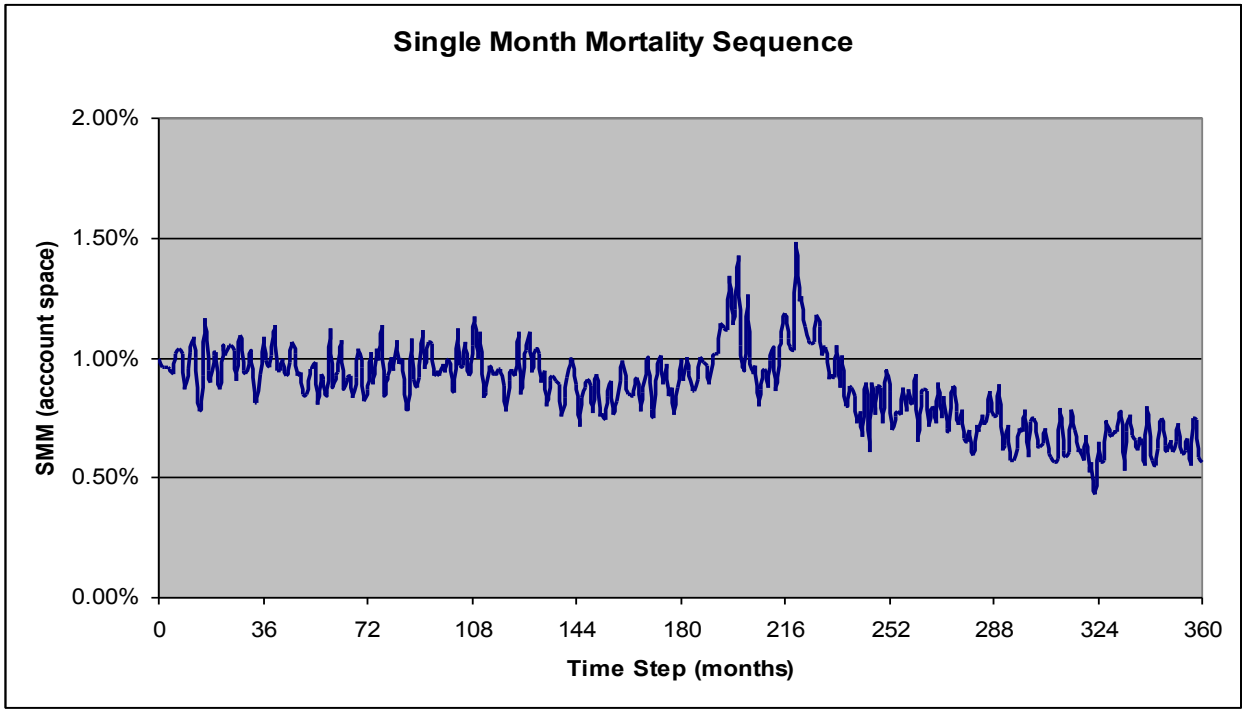
$$SMM(t) = e^{-at}\left[\alpha_0 + \beta_0\left(\frac{K}{r(t)} - 1\right)\right] + \sigma dz \qquad (3)$$

This model is a Brownian motion coupled with an inverse rate driver and a burnout factor. It recognizes explicitly the interest-rate component of repayment, which is of prime importance, as well as its burnout feature.

The relevant parameters in the prepayment model are defined as follows:

t	= time (months)
$SMM(t)$	= single month mortality at time t
$r(t)$	= CIR short-rate model output
K	= $r(t_0)$, the short rate on the closing date of the target transaction
α_0	= base prepayment rate
β_0	= interest rate effect multiplier
a	= burnout rate
dz	= Wiener process
σ	= volatility of prepayment rates

Figure 6 – Typical SMM sequence for prepayment model equation



5) Mortgage Collateral Types

Spectrum does not modify the pool valuation in any other way than to simulate its performance based on the data we request. Our view is that the data describe the risks of the transaction directly.

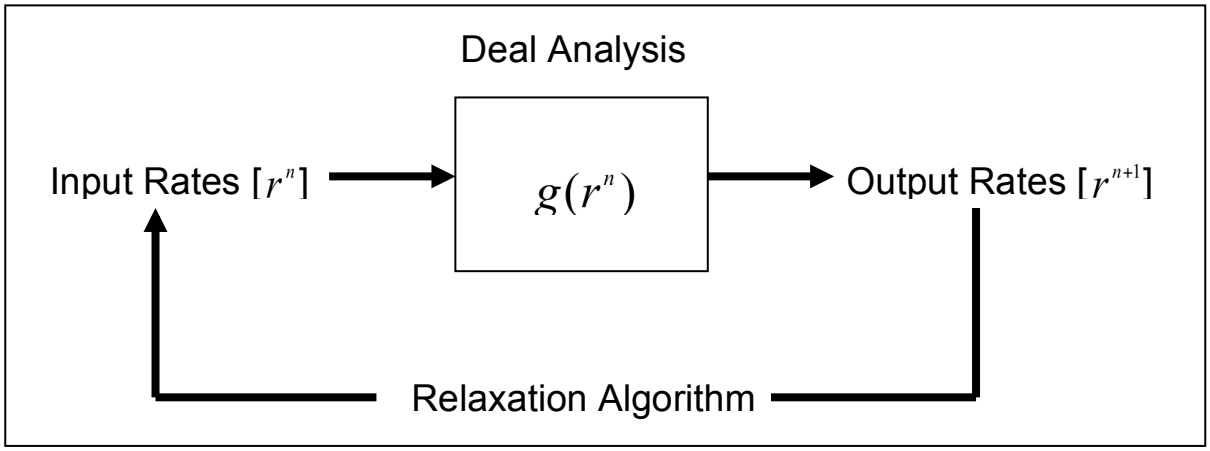
This assumption applies across the board, including to non-Qualifying Mortgages (non-QM), a class of collateral that was legally defined in 2014 by the U.S. Consumer Financial Protection Bureau (CFPB) as having any of the following features: an IO period, negative amortization, balloon payments (subject to certain carveouts), alt- or lite-documentation, terms over 30 years, points in excess of 3% of principal, or debt-to-income (DTI) ratios on loans not sold to FNMA or FHLMC in excess of a specified limit currently 43%. The DTI condition will expire July 1, 2021 and be replaced by reference interest rates within a specified band.

Non-QM loans have an additional legal risk that the borrower may initiate litigation under the Ability To Repay rule by which a lender is supposed to have vetted borrower suitabilility prior to issuing the loan. Spectrum will reflect loans that have entered into litigation in the delinquency transition matrix and default columns based on their payment status, and monitor the incidence of such litigations by issuer.

6) Ratability and Valuation

Spectrum security valuation and rating methodology is carried out identically across all ABS asset classes. This is a condensed explanation. The full version is in chapter 22 of ***Elements of Structured Finance***.

Figure 7: Rating and Valuation in Structured Finance



Spectrum uses the 1922 Banach Fixed Point Theorem [FPT] as its valuation and rating method to assess ratability and execute the rating analysis. Under the right pre-conditions, iterating a hyperbolic map (as implied by mapping provisional interest rates to new values) a unique fixed point in yield-space will exist. Then the deal is ratable and the resulting fixed yield-vector is referred to as the "Value" of the deal. Spectrum assigns letter-grade credit ratings (AAA, AA, etc.) automatically along with the fixed-point valuation when the yield-space converges.

It may also happen that the deal cannot converge onto a fixed point. Then, the deal is not ratable ("ill-posed") and the arranger must modify it on the asset- or the liability-side. Since static pools are difficult to change in response to ill-posedness, most modifications are executed on the liability side, for instance by increasing the size of the reserve account, implementing a trigger, partially wrapping the deal, etc.

7) Spectrum RMBS Credit Ratings

The value of structured securities is based solely on cash flows generated by the loan pool. Decoupling from the balance sheet of the sponsoring firm means the best indication of ABS credit quality is a cash-flow measure. The best candidate is yield-reduction, since default is ruled out *a priori* via SPC bankruptcy-remoteness, and credit spreads, by which rating differentials are expressed, are also measured on in yield.

It is a yield reduction because fixed income securities bear a fixed coupon[1]. Unfortunately, going from a default to a loss metric introduces non-linearity into the analysis. We resolve this with Banach's FPT: one of the few analytical solutions with a unique solution-vector. This resolution is achieved *via* an iterative loop like that in Figure 7 and itemized below:

1- The deal function $g(r^n)$, deemed a function of the provisional rate-vector r^n vis-à-vis the nth iteration, consists of the available cash flow model.
2- It delivers a) the average life and b) the reduction of yield of each liability tranche in the provisional bond structure.
3- These input rates and average lives are fed to a yield-curve model, resulting in output rates that should match the input rates up to a given error bound, usually in the neighborhood of 1%.

[1] For floating-rate bonds, the credit spread is fixed instead of the par yield. In such cases, the analysis is identical and based on credit spreads rather than total yield.

4- When this obtains, the iterative sequence is halted and the resulting output-rate vector, assuming par pricing, is defined as the fair market value of each security.
5- Should the yield-space iteration be seen to diverge, stop the process and inform the deal sponsor the transaction as presented is unratable.
6- The sponsor may wish to adjust elements of the collateral or structure. Spectrum analysts do not make recommendations or use the WFE as a structuring tool in the rating process.

Use of The Waterfall Editor for Ratings at Origination

Spectrum analyzes the RMBS cash flows in our proprietary Waterfall Editor [WFE] model using data provided by the sponsor in line with our required minimum set. Figure 8 illustrates principal allocations for a minimum two-tranche deal. Cash distribution is shown in Figure 9.

Figure 8 – WFE – Principal Allocations in a simple Senior-Subordinated Structure

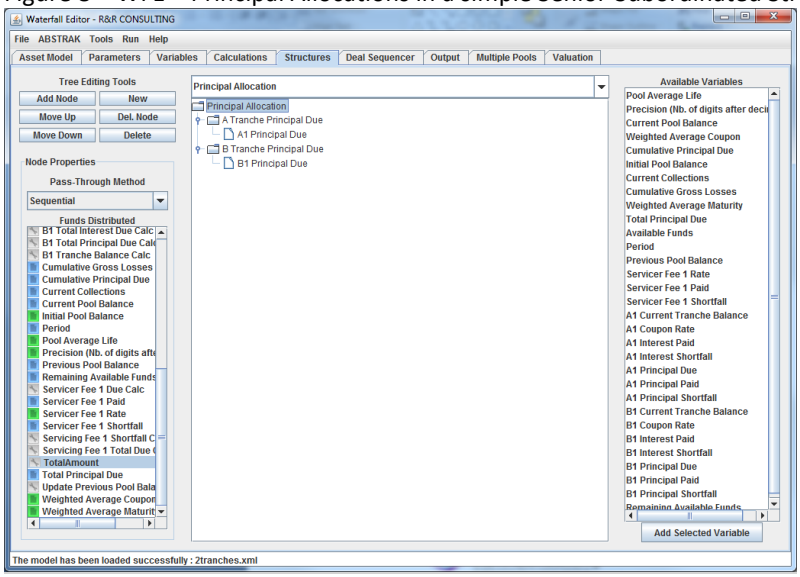
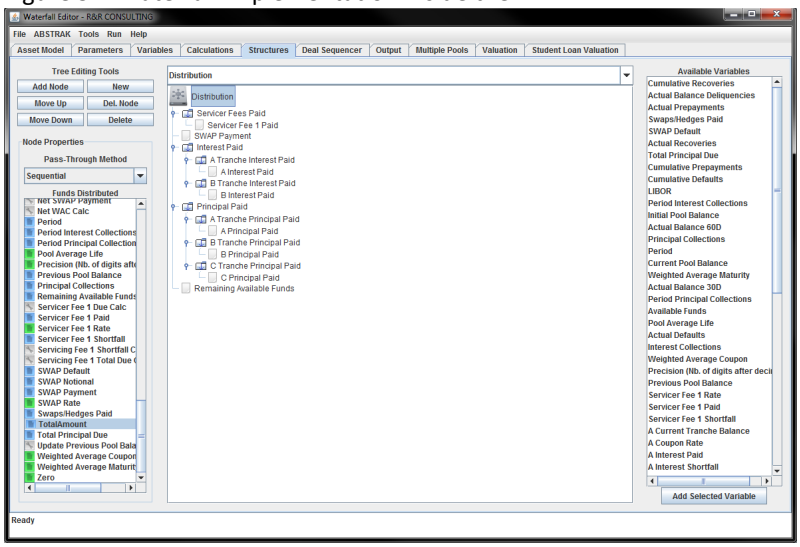


Figure 9 – Waterfall Implementation inside the WFE



Spectrum analysts build up the deal exactly as represented in the prospectus from an unlimited array of structural variables. Our analysts deconstruct and separately investigate the consistency and validity of each waterfall feature. Figure 10 shows a turbo-trigger, a nontrivial modeling exercise. Not every arranger will model precise waterfall features, but to assign ratings to the tranches, we must model them precisely.

Figure 10 – Turbo-Trigger Implementation inside the WFE

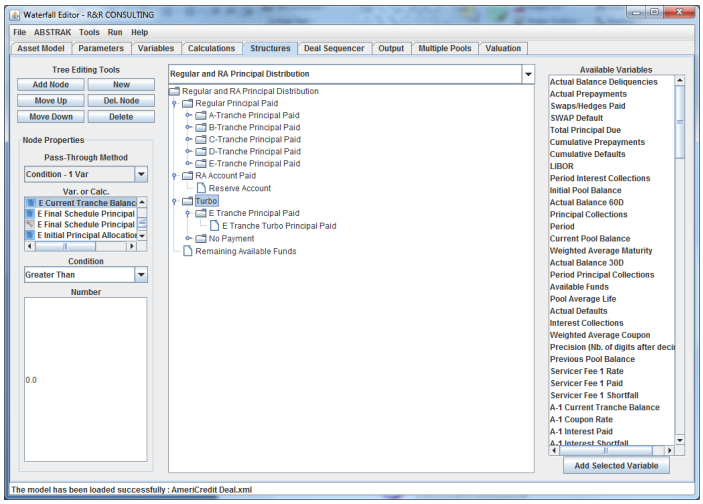


Figure 11 – WFE - Cash Flows and Bond Diagnostics

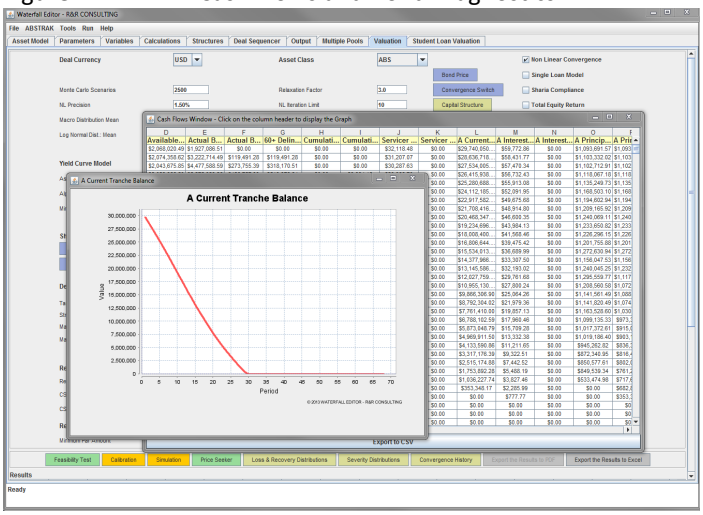
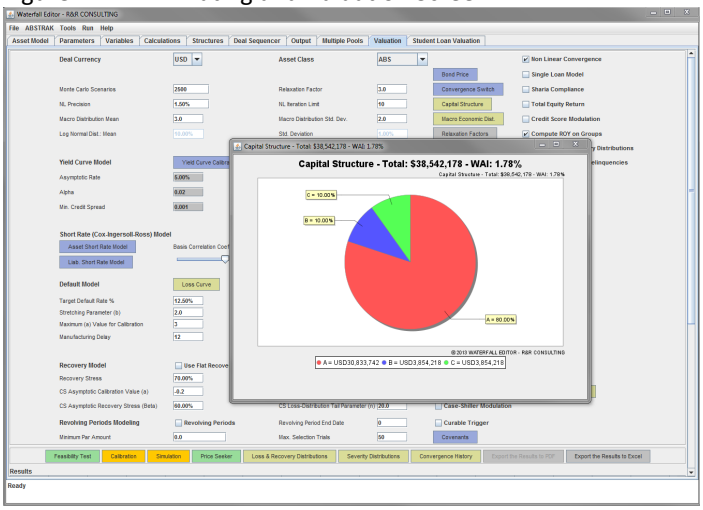


Figure 12 – WFE Rating and Valuation Screen



Finally, as Figure 12 above demonstrates, the Banach FPT-based rating and valuation of the structured securities has already been programmed inside the WFE system, consistently across asset classes, to provide sponsors or investors with full transparency on how the deal converged or else diverged.

This can even be done jointly with the client as a WebEx session.

Use of The Waterfall Editor for Ratings in the Secondary Market

Spectrum analyzes the RMBS cash flows in our proprietary ABSTRAK(R) model using servicer data to update the EDR volatility and tranche ratings.