P = PRICE
O = OAS
V =

Enter assumptions

Menu   P181h Govt   **OAS1**

OTR 10y   PG7

OPTION-ADJUSTED SPREAD ANALYSIS

US TREASURY N/B   T 4 1/8 05/15/15   99-31 /100-00   (4.13 /12) BGN @ 5:35

Calculate (P,O,V) O   **Price** P) 100   **OAS** (bp) O) - 3.03   **Volatility** V) 0.00

Cusip / ID# 912828DV9   Option Px Value: 0.00

Settle 6/17/2005   Bench settle 6/17/2005

Spread 0.0bp vs 10Y T 4 1/8 05/15/15 Govt @100 (4.125)

This bond has no embedded options.

	OAS Method	Option Free	To Maty on 5/15/2015	To Mty
Yld		4.125	4.125	4.125
Sprd		-3.0	-3.0	-3.0
M Dur	8.10		8.04	8.04
Risk	8.13		8.07	8.07
Cnvx	0.78		0.77	0.77

Model L L=Lognormal → Best model

2) Customize
Curve CMT Semi
Const. Mty Tsy Cu
Dated 6/16/2005
Settle 6/17/2005

Shift +3 (bps)

	Yield	Spread
3m	2.982	
6m	3.199	
1y	3.385	
2y	3.755	
3y	3.807	
4y	3.866	
5y	3.926	
7y	4.018	
10y	4.159	
20y	4.360	
30y	4.560	

88) REFRESH

(*) Get a bond w/ embedded options
This study is really about valuing embedded options.
This model also predicts prices (see pg 35.)

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted] Page 3 / 46

How to Use OAS1

Once you enter OAS1 <Go>, the Option-Adjusted Spread Analysis screen appears, where you can calculate values for the early redemption features for the selected security. You can also determine the bond's performance given changes in credit and/or volatility, or determine whether the selected bond's embedded option is rich or cheap.

Move your cursor to the highlighted field(s) and enter your values, then press <Go>. OAS1 automatically recalculates your assumptions.

- Enter 1 <Go> to display the OAS1 Saved Assumptions window, where you can change the Yield Adjustment Method.

- Enter 2 <Go> to display the Yield Curve Customization window, where you can enter Yield rates, display Spot or Forward Rates, and select a Standard or Expanded Curve.

- Enter 3 <Go> to display the Yield Spreads window, where you can enter yield spreads.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted] Page 4 / 46

How to Determine a Bond's Performance Given Changes in Credit and/or Volatility

From the Option-Adjusted Spread Analysis screen, enter your values in the highlighted Volatility and Spread fields, then press <Go> to automatically recalculate your assumptions.

<HELP> to contact our 24/7 Help Desk, <MENU> to return. Govt **OAS1**

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted] Page 5 / 46

How to Determine Whether Your Bond's Embedded Option is Rich or Cheap

From the Option-Adjusted Spread Analysis screen, enter your values in the highlighted Price, Volatility, and Spread fields, then press <Go> to automatically recalculate your assumptions.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted] Page 6 / 46

Option-Adjusted Spread Analysis Screen

The current market information for the bond appears below the header. The Market Quote screen, Q, displays further information. The following sections also appear:

- Calculate POV Section
- Customize Section
- Redemption Schedule Section
- Methodology Section
- Model Section

HELP FOR OPTION-ADJUSTED SPREAD ANALYSIS

Search **OAS1** <HELP> for:

- Calculate POV Section

Depending on the security you select, some or all of the following information may appear:

Calculate (P,O,V):
The value that calculates. The dropdown menu displays a list of choices.

Remember
If you calculate the Price [P], the calculated value indicates where the bond should be trading given a spread to the yield curve specified in the Curve field.

Price:
The ask price of the bond. The Price Provider Search List screen, PCS, displays further information on changing your pricing source.

OAS (bp):
The option-adjusted spread in basis points (bp). OAS is a methodology using option-pricing techniques to value the embedded options risk

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for:

component of a bond's total spread. Embedded options are call, put, or sink features of bonds. This represents the incremental return due to credit risk.

Remember

The option-adjusted spread is not derived from one point on the curve, but to a series of rates that coincide with the potential cash flows of the bond to maturity.

Fwd Strike:

Appears only when the Black Swaption model is selected. The projected at-the-money forward coupon for the term remaining on the bonds from the call date.

ATM Vol:

Appears only when the Black Swaption model is selected. The current interpolated at-the-money implied swaption volatility matching the structure of the bond.

Skew Adj Vol:

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for: [redacted]

Appears only when the Black Swaption model is selected. The volatility obtained by applying an adjustment factor (combining OAS-Adjusted Forward Par yield and Coupon rate) to the base volatility, determined from ask, bid, or mid price.

Use Skew Adj Vol:
Appears only when the Black Swaption model is selected. [Y] indicates that the Skew Adjusted Volatility is used. The Calculations section of this guide displays further information on ATM Vol adjusted for skewness.

Volatility:
Appears when the Lognormal [L], Normal Mean Reverting [N], or Lognormal with Mean Reversion [R] models are selected. For the Lognormal [L] and Lognormal with Mean Reversion [R], this is the annualized volatility of the short rate, in percentage terms. For Normal Mean Reverting [N], this is the annualized volatility of the short rate, in absolute terms. These determine the amount of future interest-rate fluctuation.

Remember
The implied volatility values for taxable fixed income securities are

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for: [redacted]

calculated from your default settings in the Volatility Default Settings function, SWYV, while the implied volatility values for municipals are from various municipal Fair Market Sector Curves, FMC.

Cusip/ID:
The CUSIP or Bloomberg identification number for the security.

Option Px Value:
The option price value is the present value of the option, in price points. For callable bonds this is a positive value that represents the theoretical cost of buying back the call option(s) that the investor is short. For put options this is a negative value that represents the amount an investor would be paid for selling the long put option back to the issuer. The Calculations section of this guide displays further information.

Remember
Sinks are considered partial calls and typically contribute a positive number to the option value. However, there are cases in which embedded sinks act like partial puts and contribute negative option value. For example, if the bond has an embedded call worth $3.00 to the issuer and an

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for:

embedded put worth $2.00 to the bondholder, the Option Value is reported as $1.00 ($3 - $2).

Settle:
The date securities must be delivered and paid for to complete a transaction.

Vega:
Appears when either the Black-Derman-Toy [B], Normal Mean Reverting [N], or Lognormal with Mean Reversion [R] models are selected. The option price change per a 1% change in volatility.

Spread (amount) bp vs:
A comparison of the basis point (bp) spread to the benchmark government bond. The number of years until maturity, ticker symbol, coupon, maturity, ask price, and yield of the benchmark government bond appear.

Remember
To compare the selected bond against a benchmark based on maturity instead of duration, enter OAS1 M <Go>.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for: [redacted] Page 12 / 46

- Customize Section

Depending on the security you select, some or all of the following information may appear:

Curve:
The curve code, name, and its settlement date used in the analysis. A dropdown menu displays a list of curves.

Shift (amount) (bps):
The total number of basis points to shift the entire curve. You can change the value to perform analyses using parallel yield curve shifts. To customize the yield curves, enter 2 <Go> for the Yield Customization window.

Yield:
The yields corresponding to the curve you select.

Remember
Blanking out yields in the Yield Curve Customization window interpolates missing points from the remaining values.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted]

Spread:
Appears when the Lognormal [L], Normal Mean Reverting [N], or Lognormal with Mean Reversion [R] models are selected. The interpolated spread to the yield curve specified in the Curve field.

YldVol:
Appears when the Black-Derman-Toy [B] model is selected. The full (zero-coupon) yield volatility curve.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for: [redacted]

- Redemption Schedule Section

Depending on the selected security's redemption schedule, the following information appears in the lower left corner of the page:

Call Schedule:
Appears only if the bond has an embedded call option. The call schedule contains the security's redemption schedule, dates and prices, and includes only those calls falling on or after the settlement date.

Put Schedule:
Appears only if the bond has an embedded put option. The put dates and prices. The put schedule includes only those puts falling on or after the settlement date.

Sink Schedule:
Appears only if the bond has an embedded sinking fund provision and displays the sinking fund dates and amounts. The {Call/Put/Sink} Schedule Screen section of this guide displays further information.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for: [redacted]

- Methodology Section

The section in the middle of the screen displays a comparison of several analyses using different methodologies. The following methodologies appear:

OAS Method:
The OAS calculations taking into account all embedded options. A yield does not appear because OAS considers all possible redemptions simultaneously, making it impossible to define a single yield. The spread appears in the OAS (bp) field.

Option Free:
The yield of the security if all options are removed. It is assigned a price by adding the values in the Price and Option Value fields. This price is then converted to a yield-to-maturity, which appears in this column.

Remember
The spreads in this section represent the interpolated yield spread to the selected yield curve that appears in the Customize Section to the right.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted]

To {Put/Call/Maty} on {date}:
Traditional cash flow analysis is applied to one of several possibilities, depending on the situation. The specific case is described at the top of the column as To Call for callable securities, To Put for putable securities, or To Maty for sinkable securities. Typically, this column displays yield to the refunding call date. If this date precedes settlement, the column displays yield-to-next-call. If puts are present, a decision rule determines whether to display yield-to-put or yield-to-call.

To Mty:
The analysis of the bond as if it were a bullet trading on a yield-to-maturity basis.

The following pricing and sensitivity measures also appear:

Yld:
The yield of the bond.

Sprd:
The spreads in this section represent the interpolated yield spread,

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for: [redacted]

compared to the selected yield curve that appears in the Customize Section to the right. The spreads calculate the appropriate yield (to Maturity/Call), then subtract the interpolated yield that corresponds to the maturity/call date of the bond being analyzed.

M Dur:
The percentage price change of a bond for a given change in yield. The higher the modified duration of a bond, the higher its risk. The Calculations section of this guide displays further information on Ad/Mod Duration.

Risk:
A measurement used by Bloomberg to indicate price sensitivity given shifts in interest rates. Risk is 100 times the price value of a basis point change in yield.

Cnvx:
The rate of change of duration as yields change. A bond exhibits positive convexity when its price rises more for a downward move in its yield than its price declines for an equal upward move in its yield. The Calculations

section of this guide displays further information on convexity.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted]

- Model Section

The following information appears:

Model:
The model you choose indicates the method of determining and predicting future interest rates. As a point of reference, Bloomberg fair value (BFV) calculations use the Lognormal [L] model. The Calculations section of this guide displays further information on different models.

Once you select a model type, the following information may appear:

Mean Reversion Speed:
Appears only for the Normal Mean Reverting [N] and Lognormal w/Mean Rev [R] models. The mean reversion speed is the force with which short-term interest rates are pulled back to normal levels in the event they deviate from such levels.

For example, during the ERM crisis of 1993, certain Scandinavian overnight rates jumped above 500%, but this situation did not last for more than a few days. Mean reversion attempts to model the empirically observed tendency for rates to move back to reasonable levels. The mean reversion speed is approximately the fraction of the deviation that reverts to the implied forward rate annually. The typical range for this parameter is between 0.001 (a negligible amount of mean reversion) and 0.1 (a large amount of mean reversion).

Exercise Premium:
Appears only for callable securities. Since there are some costs associated with calling a bond, you can provide a dollar value to the amount that the call must be in-the-money before the issuer exercises the call. Internally, the model adjusts the call schedule by adding the exercise premium to the call strike prices.

OAS1 Saved Assumptions Screen

Once you enter 1 <Go> to save your assumptions, the following information appears:

Model:
The method of determining and predicting future interest rates. As a point of reference, Bloomberg Fair Value (BFV) calculations use the Lognormal [L] model. For a list of choices, move your cursor to the highlighted Model field. The Calculations section of this guide displays further information on different models.

Mean Reversion Speed:
Applicable only to the Normal Mean Reverting [N] and Lognormal w/Mean Rev [R] models. The mean reversion speed is the force with which short-term interest rates are pulled back to normal levels in the event they deviate from such levels.

Exercise Premium:
Applicable only for callable securities. Since there are some costs

associated with calling a bond, you can provide a dollar value to the amount that the call must be in-the-money before the issuer exercises the call. Internally, the model adjusts the call schedule by adding the exercise premium to the call strike prices.

Volatility:
The annualized volatility of the short rate, in percentage terms. This determines the amount of future interest-rate fluctuation. It does not appear for the [B] Black-Derman-Toy model. The Black-Derman-Toy model uses a full (zero-coupon) yield volatility curve. The implied volatility values for taxable fixed income securities are from your default settings in the Volatility Default Settings function, SWYV, while the implied volatility values for municipals are from various municipal Fair Market Sector Curves, FMC.

Remember
When you enter values for any two of the Calculate options (Price, OAS, or Volatility), the Calculate field defaults to the letter code for the value you did not enter. The Calculations section of this guide displays further information on bond valuation and implied volatility.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for:

(Use constant volatility value?):
[Y] saves the constant volatility value, while [N] does not.

Saving USD Curve:
The curve code. For a list of choices, move your cursor to the highlighted Curve field on the Option-Adjusted Spread Analysis screen.

The following information applies to IYC curves only: TRY this

Use BGN Price:
[Y] or [N] indicates whether or not to use the Bloomberg Generic Prices in the OAS1 calculations.

Bid/Ask:
A dropdown menu displays the following options for prices in the OAS1 calculations: bid [B] or ask [A].

Interpolation Method:
The type of interpolation to use on the International Yield Curve function,

IYC. A dropdown menu displays a list of curve options.

Yield Adjustment Method:
The method of yield curve adjustment. OAS1 allows you to select from different methods for adjusting the yield curve into a constant maturity curve. The BLOOMBERG Par Curve and BMA Constant Maturity methods are computed on the fly from latest available prices on a given reference curve. In all cases, the spreads appear in basis points and are added to the nominal yields displayed on the screen. A dropdown menu displays the following list of options:

- B - The Bloomberg par curve method:
This method adjusts the yields of the reference curve such that a par coupon curve is constructed. It accounts for the fact that a specific bond's actual maturity may not exactly match the nominal maturity AND any premium or discount in a specific bonds price. The spreads are calibrates so that any of the bonds that make up a given reference curve will price at a zero OAS1 to that curve.

- A - BMA constant maturity method:

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted]

This method uses a spline technique to adjust the bonds in a given reference curve for the fact that the maturities are not equal to the nominal maturities. It does not account for the fact that the bonds in the curve are not priced at par.

- C - Custom method:
Appears when any of the default spreads are modified.

- N - No Adjustment:
Clears out all of the spreads.

Yield Curve Customization Screen

Once you input your assumptions and enter 2 <Go>, the following information appears:

Display:
A dropdown menu displays the following options that customize the yield curve:

- Spot Rates [S]:
The theoretical yield on a zero-coupon Treasury.

- Forward Rates [F]:
A trade done for settlement on a date beyond the spot date.

Curve:
A dropdown menu displays the following options to customize the yield curve:

- Standard [S]:
The standard curve uses 11 key maturity points to generate the spot rates

used in the calculation. All other points are interpolated.

Expanded (32 pts) [X]:
The 32 point expanded curve allows you to customize the rates at non-standard maturities to reflect, for example, the liquidity premium at different points along the yield curve.

Yield:
The yields corresponding to the selected curve.

Spot:
The spot rate corresponding to the selected curve.

FWD:
The forward rate corresponding to the selected curve.

Y.Vol:
The full (zero-coupon) yield volatility corresponding to the selected curve.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted] Page 28 / 46

{Call/Put/Sink} Schedule Screen

Depending on the selected security's redemption schedule, the following information appears in the lower left corner of the screen:

Call Schedule:
Appears only if the bond has an embedded call option. The call dates and prices. The call schedule includes only those calls falling on or after the settlement date.

Put Schedule:
Appears only if the bond has an embedded put option. The put dates and prices. The put schedule includes only those puts falling on or after the settlement date.

Sink Schedule:
Appears only if the bond has an embedded sinking fund provision and displays the sinking fund dates and amounts. The following information appears with this option:

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for:

- OUTSTANDING:

The bond's current amount outstanding, in thousands.

- ISSUED:

The bond's original issue amount, in thousands.

- SCHED BAL:

The amount currently outstanding if the issuer sinks the minimum possible amount, in thousands.

- VOLUNTARY:

Any voluntary sink amount allowed.

Mkt Purchase?:

OAS1 models the mandatory component of sinking fund provisions, ignoring the voluntary provisions. In some cases, issuers are permitted to satisfy their sinking fund requirements by purchasing bonds in the open market. When this is not permitted, the issuer is required to purchase the necessary bonds from the bond holders at the sinking fund price, either via lottery or on a pro-rata basis.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for:

[Y] indicates that the model assumes the issuer is permitted to buy bonds via open market purchases. [N] indicates the sinking fund is modeled on a pro-rata basis. In the former case, the sinking fund performs like a series of partial calls, whereas in the latter case, the effect is mixed. When the bond is trading at a premium, a pro-rata sinker appears to the bondholder as a series of issuer-held partial calls. If the bond is trading at a discount to par, a pro-rata sinker appears as a series of partial puts.

HELP FOR OPTION-ADJUSTED SPREAD ANALYSIS

Search **OAS1** <HELP> for:

SHORTCUTS

OAS1 {price} <Go>
Specifies the price in the highlighted Price field.

OAS1 {model code} <Go>
Specifies the model.

Remember
- Model codes are Lognormal [L], Black-Derman-Toy [B], Normal Mean Reverting [N], and Lognormal with Mean Reverting [R].

- You can combine these shortcuts.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for:

CALCULATIONS

ATM Vol Adjusted for Skewness
sqrt(F/c)

where:
F = the OAS adjusted forward strike
c = the coupon

Ad/Mod Duration
Ad/Mod Duration = [duration / (1 +(IRR/M))]

Internal Rate of Return

where:
IRR = the internal rate of return
M = the number of compounding periods per year

Option Price Value at a Constant OAS
The option price relates to the bond price in the following equation:

Bullet Bond Price - Option Embedded Bond Price = Option Price

Convexity
(P+ + P-) - 2Po / (dy)**2 * Po

where:
Po = price at current OAS
P+ = price at current OAS + dy
P- = price at current OAS - dy
dy = 50bps or 10bps, depending on whether the bond has options or not.

Volatility
The volatility information is derived from the Tullett & Tokyo interest rate swaption volatility data set. You can display this information on the Tullett Financial Swaption Volatilities function, TTSV. The volatility information is determined by a mapping routine that matches the structure of a bond to an offsetting swaption structure.

This same routine is currently used in this function. For example, a five-year maturity bond that is callable in one-year uses the one-year

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

option on a four-year swap volatility that appears on TTSV. Volatility for a structure not matching the exact terms available on TTSV is mapped using bilinear interpolation. Bullet bonds, bonds with no embedded options, use a volatility of zero.

This volatility methodology is used regardless of any personal defaults set using the OAS User Defaults function, OASD. TTSV provides real-time volatility data. Therefore, different results may occur depending on the timing of the analysis.

Bond Valuation

When comparing bonds, the bond with the higher spread is viewed as the less expensive security. This does not necessarily represent better value, however, since the bonds can trade in different sectors. For example, a bond rated A1 would have a positive spread to U.S. Treasuries. The more closely the bonds resemble each other, the more you can assign a meaningful value to the OAS comparison.

Implied Volatility

You can calculate implied volatility for the Lognormal [L], Normal Mean

Reverting [N], and Lognormal with Mean Rev models [R]. The value of an option is heavily influenced by the level of volatility. Generally, the greater the volatility, the more valuable the option. By specifying a price, an OAS value, and a model, OAS1 generates an implied volatility.

For callable bonds, the bond with the higher implied volatility is more valuable because the imbedded call option results in a higher relative price (since the option is being priced at the higher implied volatility). For example, if the imbedded call of one bond is very valuable and the imbedded call of the second bond is deeply out-of-the-money, the higher implied volatility can apply to the option that represents the smaller component of the bond's total value.

Model-Predicted Price

If you specify an OAS value and a volatility level (or curve), OAS1 generates a model-predicted price. You can compare this price against the bond's market price or the model-predicted price of a comparable security.

Model Descriptions

OAS methodology provides a consistent framework for portfolio managers to

Conclusion:
LOGNORMAL is the best (pg 37)
R MODEL is next best (pg 44)

analyze a broad range of securities. Each particular OAS interest-rate model requires its own inputs. The common inputs are the bond's description and a base yield curve. The following model descriptions will be outlined:

- L model: a yield volatility
- B model: a yield volatility curve
- N model: a yield volatility and a speed of mean reversion
- R model: a yield volatility and a speed of mean reversion
- S model: a forward par rate volatility

OAS Analysis *

Predicting

In general, yield volatility quantifies how likely interest rates are to move from current levels over time. For example, for the Lognormal model [L], a yield volatility of 10% says that there is a 70% chance that rates stay within 10% of current levels over one year's time (that is, within one standard deviation).

OAS analysis extends traditional valuation methods. For callable bonds, standard cash flow analysis states that if the bond is trading at a discount, then evaluate it using yield-to-maturity. If the bond is trading

L MODEL - Best

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at a premium to a future strike price, evaluate it using a yield-to-call basis. Such an analysis asserts that the bond trades at a fixed yield between settlement and the assumed redemption date. Similarly, all intermediate cash flows from coupons earn at the fixed yield. In practice, however, other possibilities must be taken into account. OAS analysis considers millions of ways that interest rates can evolve over time and considers how the bond performs in each case, taking into account reinvestment of coupons and potential calls.

Remember
The treatment of volatility is the most important difference between each model.

L model - A Yield Volatility
L: The Lognormal model postulates that the short rate follows a lognormal process, described as:

r(t) = U(t) * exp.[v * z(t)]

where:

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**

Search **OAS1** <HELP> for: [redacted]

r(t) is the (random variable) short rate at time t, U(t) is the median of r(t), v is the volatility of the process, and z(t) is a standard Brownian motion, with z(0) = 0, var.[z(t)] = t (variance of z(t) is t).

This process is written as:

dr/r = m(t) dt + v dz

This is a standard differential equation for a stochastic process, where r * m(t) * dt is the drift and v is the volatility. This model is quite widespread because of its relatively straightforward formulation. The lognormal model underlies the Bloomberg Fair Value calculations and the default model for Bloomberg OAS analysis (e.g. OAS1, OAS2, BFV, TRA, SW, etc.). Both equations describe the process r(t), where there is an unknown function, U(t) and m(t) respectively. In practice, these functions are implied by the initial conditions for the process (i.e. today's yield curve). The implications for this model follow three assumptions. When rates are high the volatility of rates is greater than when rates are low. Rates can never become negative (as is evident from the first of the above equations).

Conclusion

The variance of the distribution of log [r(t)] grows linearly over time (more precisely, var[log r(t)]=t * v^2). This last property is considered a model weakness, in that a single volatility is used for the life of the underlying bond. One alternative formulation, a generalized lognormal model, allows for a volatility curve. Normal ranges for v are 1% (low) to 30% (high), with typical levels between 4% and 15%.

B model - A Yield Volatility Curve

B: The Black-Derman-Toy model is a generalized form of the Lognormal model [L]. The mathematical formulation of the model is:

$$dr/ r = (g(t) + [s'(t) / s(t)] * \log(r)) dt + s(t) dz$$

where:

g(t) is an unknown function (like U(t) and m(t) above) that is implied by the initial conditions for the process, namely today's yield curve.

This model provides for a time-varying short-rate volatility, s(t). The Lognormal model [L] can be obtained as a special case of this model by setting s(t) constant for all t.

As with the [L] model, the drift function g(t) is implicitly determined by today's yield curve. In its original formulation by Black, Derman and Toy, the function s(t) is implicitly determined by a curve of (instantaneous) volatilities of (log-) yields of zero coupon bonds of different maturities. In other words, if market prices are known for a set of options on (zero-coupon) bonds of different maturities, this model could be calibrated to simultaneously correctly price all of them.

According to the model, this forces (implies) the path s(t) of future short-rate volatility, completely analogous to the way in which today's yield curve implies (the median of, or the drift of) the future short rate.

In contrast to the Lognormal model [L], which requires a high volatility to accurately price a short-term option on a short-term bond and a lower volatility to price a short-term option on a long-term bond, a single volatility is used throughout the life of the bond.

This leads to an inconsistency because the tree of short rates that represents the stochastic process is dependent on the volatility specified. If different volatilities are used to price options on different bonds, then their trees are different. But the trees represent prevailing short rates, independent of the specific bond analyzed. In the specific case just mentioned, where an option on a long bond is evaluated with a lower volatility than an option on a short bond, the near term cash flows of the long bond receive different discounting than the similar cash flows in the case of the short bond. This inconsistency in the [L] model is fixed in the [B] model.

Remember
The yield volatilities are for zero-coupon yields. Market-determined default values for the volatility curve are used as the default curve on this screen. This volatility curve is the one-year historical volatility calculated from the FMC curve used. Enter VOL <Go> and then 4 <Go> for Bloomberg Data Set Yield Curve Volatilities.

YLD CRV VOLS

Empirically, several studies confirm that the yield volatilities of short-term bonds are higher than the yield volatilities of longer term bonds. If you enter a declining volatility curve, it is not a curve of short rate volatilities at future horizons.

The [B] model contains some mean reversion, which is most easily seen if we do a transformation of variables. Writing the basic formula in terms of log r instead of r:

d [log r] = -[s'(t)/s(t)] * [h(t) - log r] dt + s(t) dz

which displays clear mean reversion in log r, provided that s'(t) is negative (i.e. that s(t) is a monotonically decreasing function). This is referred to as a quasi-mean reversion because s(t) is implied by the initial yield and volatility curves and is not explicitly described. Moreover, s(t) is not guaranteed to be monotonically decreasing, so movement away from the mean can occur.

N model - A Yield Volatility and a Speed of Mean Reversion
N: The normal, mean-reverting, also referred to as the Hull-White/Jamshidian, Extended Vasicek, or Gaussian model, differs from the two lognormal-type models, [L] and [B], by hypothesizing that the distribution of the short rate r(t) at time t is given by a normal

distribution, as opposed to a lognormal distribution.

This model explicitly incorporates mean reversion, a property that roughly states that if rates jump far away from 'historical' levels, then pressure on these rates exist to return to a 'historical' range. This is a particularly attractive feature since it appears to be supported by empirical data.

The mathematical formula of the model is: dr = (b(t) - ar) dt + s dz

As in the [L] model, the volatility term here is constant. However, the nature of this model dictates that the size of the "unexpected component" - s dz - is independent of the level of rates. As a result, rates can become negative in this model, a clear drawback. Some researchers advocate the model because it is tractable, allowing for a closed-form solution for the price of a European option on a discount bond. A valid range for s is 10bp (low) to 200bp (high), with typical levels between 75bp and 140bp. The default value is 120bp.

As with the [L] and [B] models, the (N) model defines a function implicitly, in this case b(t), in order to match the initial yield curve.

Mean reversion assumes that if interest rates rise to some very high level (relative to historical ranges), then pressure on interest rates to revert to a (historically) "reasonable" level would exist (and, similarly, for very low rates reverting to higher levels). This prohibits rate paths from becoming stuck at levels that seem outside a reasonable range. A typical range of values for mean reversion is 0.001 for negligible effects to 0.1, which is a relatively high mean reversion. The default value is 0.03.

A weakness of the NMR model is that rate volatility is absolute and not relative. This is in contrast to the [B] and [L] models, where volatility is stated as a percentage change from current levels. Empirically, higher yields produce higher absolute changes in yields, so percentage changes are more appropriate. Several empirical studies have considered the appropriate form of the volatility component and have concluded that the Lognormal form for volatility is superior to a normal or a square root specification.

R model - A Yield Volatility and a Speed of Mean Reversion
R: The Lognormal mean-reverting model is a generalization of the Lognormal

R-MODEL

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Search **OAS1** <HELP> for: [redacted]

[L] model, which incorporates mean reversion. This model has the advantage of the Lognormal model (the short rate cannot become negative) with the added feature of mean-reversion. The latter ensures that the width of the distribution of the short rate at long maturities is bounded and centered around the forward spot rate. The mathematical formulation of this model is:

$$d \log(r) = (b(t) - a \log(r))\, dt + v\, dz$$

As in the [L] and (N) models, the volatility term here is constant. The function b(t) is set by matching the model to the initial yield curve. The default value of the mean-reversion parameter is 0.03.

If we take the mean-reversion parameter to zero, we recover the [L] model with $b(t) = m(t) - v^2 / 2$.

Remember

The [R] model with mean-reversion set to zero does not give precisely the same prices as the [L] model, for numerical reasons. The [M] model uses a trinomial tree for valuation, while the [L] model uses a binomial tree.

HELP FOR **OPTION-ADJUSTED SPREAD ANALYSIS**
Search **OAS1** <HELP> for: [redacted] Page 46 / 46

S model - A Forward Par Rate Volatility

S: The current S-model assumes a bond with a single par European embedded call and no other embedded optionality, and a 30/360 Securities Industry Association (SIA) end of month (EOM) day type and regular cashflow stream (dates and amounts).

The option is valued by a swaps methodology that essentially assumes that the forward par swap rate is lognormally distributed at the exercise date. The default volatility input is a skew-adjusted at-the-money swaption volatility.

The value of the option is subtracted from the present value of the bond without option and the result is adjusted for accrued interest and reported. It should be noted that the screen's volatility input is not that of the short rate, so that varying the volatility highlights the effects of uncertainty about a forward par swap rate. This is unlike models [L], [R], and [N] where varying the volatility input highlights the effect of uncertainty about the short rate.

<HELP> for personal assistance, <MENU> to return.